CHAPTER -1 Introduction of Computer Graphics

A Brief Overview of Computer Graphics, Areas of Applications

Computer Graphics Field is related to the generation of graphics or image using computer which includes the creation, storage and manipulation of image objects. Thus, computer graphics is an integral part of all computer user interface and is necessary visualizing 2-D, 3-D objects in all most all areas such as education, science, engineering, medicine, commerce, research, advertising and entertainment.

Components of Computer Graphics:

Interactive computer graphics consists of three components, such as:

1) Digital Memory buffer/ Frame Buffer
2) Video Monitor/TV monitor
3) Display Controller

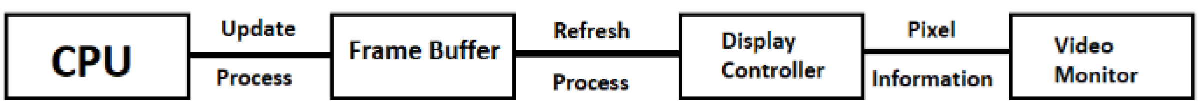

Fig: Components of Computer Graphics

Digital Memory Buffer (Frame Buffer)
This is place where images or pictures are stored as an array (matrix of 0 and 1, 0 represents darkness and 1 represents images or picture).

Frame buffer is the video RAM (V-RAM) that is used to hold or map the image displayed on the screen. The amount of memory required to hold the image depends primary on the resolution of the screen image and also the color depth used per pixel. The formula to calculate how much video memory is required at a given resolution and bit depth is quite simple.

Usually frame buffer is implemented using rotating random access semiconductor memory. However, frame buffer also can be implemented using shift registers

Note: The formula to calculate how much video memory is required at a given resolution and bit depth is:

Memory in MB = (X-resolution) * (Y- Resolution) * (Bits per Pixel)

1. TV Monitor:
Monitor helps us to view the display and they make use of CRT (Cathode Ray Tube)

2. **Display Controller:**

It is an interface between digital memory buffer and TV monitor. The main function of this is to pass the contents of frame buffer to the monitor. The display controller reads each Successive byte of data from the frame buffer memory and converts 0's and 1's into corresponding video signal. This signal is then fed to the TV monitor to produce a black and white picture on the screen. Now, display controller is recognized as display card and one of our choices can be VGA card with a resolution of 640 x 480.

Until early 1980's Computer Graphics was a small specialized field

- **Hardware** was expensive
- Graphics based **application programs** that were easy to use and cost effective were few
- PCs with built in raster graphics displays such as the **Xerox Star, Apple Macintosh** and **the IBM PC** – popularized the use of **bitmap graphics** for user computer interaction.
- A bitmap is a 1 and 0s representation of the rectangular array of points on the screen.
- Each point is called a pixel, short for **"picture elements".**
- Once the bitmap graphics became **affordable** an explosion of easy to use, inexpensive graphics based user interfaces allowed millions of new users to control simple low cost application programs such as **word processors, spreadsheets** and **drawing programs**
- The concept of a **"desktop"** now became popular metaphor for organizing screen space.
- Even people who do not use computers encounter computer graphics in TV commercials and as cinematic special effects.
- Thus computer graphics is an **integral part** of all computer user interfaces, and is indispensable for visualizing 2D, 3D objects in all most all areas such as **education, science, engineering, medicine, commerce the military advertising** and **entertainment.**

Early History of Computer Graphics:

- Crude plotting of hardcopy devices such as teletypes and line printers dates from the early days of computing
- The **whirlwind computer** developed in 1950 at the Massachusetts Institute of Technology (MIT) had **computer driven CRT displays** for output.

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- **SAGE** air-defense system developed in the middle 1950s was the first to **use command** and **control CRT display consoles** on which operators identified targets with light pens

- The **General Motors** DAC system for **automobile design** and the **Itek-Digitek system** for **lens design**

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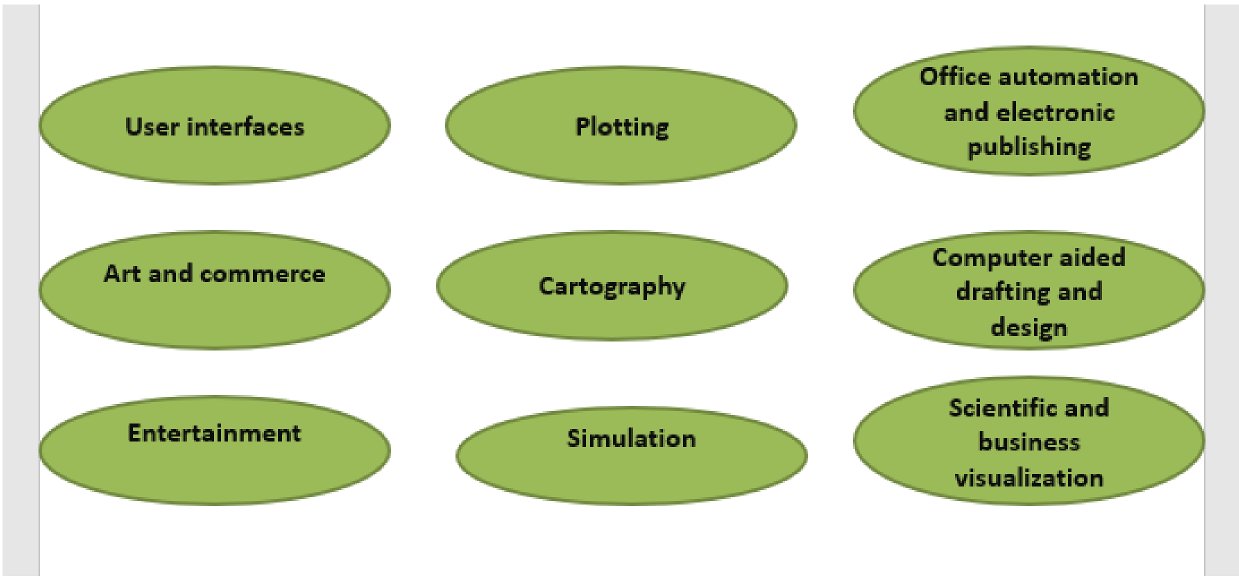
- Later on **Sketchpad system** by Ivan Sutherland came in light.
- The beginning of **modern interactive graphics**.
- **Keyboard** and **light pen** used for pointing, making choices drawing
- Prospects of the use of **(CAD)** and **(CAM)** in computer, automobile, and aerospace manufacturing Drafting and Drawing activities
- By the mid 60s, a number of **commercial products** using these systems had appeared
- At that time only the **most technology intensive organizations** could use the interactive computer graphics where as others used **punch cards**, a non-interactive system .

Reasons:

- The **high cost of graphics hardware** – at a time when automobiles cost a few thousand dollars, computers cost several millions of dollars, and the first commercial computer displays cost more than a hundred thousand dollars
- The need for large scale **expensive computing resources** to support massive design database
- The difficulty of writing large interactive programs using **batch oriented FORTRAN programming**
- One of a kind, **non-portable software,** typically written for a particular manufacturer's display devices.

- (When software is non-portable, moving to new display devices necessitates expensive and time consuming rewriting of working programs)
- Thus **interactive computer graphics** had a limited use when it started in the early sixties but it became very common once the **Apple Macintosh** and **IBM PC** appeared in the market with affordable cost

Applications of Computer Graphics



Display Technology:

The display systems are often referred to as Video monitor or Video display unit. The most common video monitor that normally comes with a PC is the Raster scan type. Some of the most common types of Display systems are

1. Raster scan display
2. Random scan display
3. Flat panel display

The display device are often referred to as Output devices. The most commonly used output devices in a graphics system is video monitor and the operation of most video monitors is based on the Cathode Ray Tube (CRT) design.

Fluorescence / Phosphorescence

- A phosphors fluorescence is the light emitted as the very unstable electrons lose their excess energy whole the phosphor is being struck by electrons

- Phosphorescence is the light given off by the return of the relatively more stable excited electrons to their unexcited state once the electron beam excitation is removed

Persistence

- A phosphor's persistence is defined as the time from the removal of excitation to the moment when phosphorescence has decay to 10 percent of the initial light output

- The range of persistence of different phosphors can reach many seconds

- The phosphors used for graphics display devices usually have persistence of 10 to 60 micro seconds

- A phosphor with low persistence is useful for animation and a high persistence phosphor is useful to highly complex static pictures

The factors affecting the CFF are:

- Persistence: longer the persistence the lower the CFF But the relation between the CFF and persistence is non linear

- Image intensity: Increasing the image intensity increases the CFF with non linear relationship

- Ambient room light Decreasing the ambient room light increases the CFF with nonlinear relationship

- Wave lengths of emitted light

- Observer

Refresh rate

- The refresh rate is the number of times per second the image is redrawn to give a feeling of un-flickering pictures and it is usually 50 per second.

- To maintain stable image the electron beam must sweep entire surface of the screen and then return to redraw it a number of times per second. If the electron beam takes too long to refresh, it becomes as a flicker in the image

- As the refresh rate decreases flicker develops because the eye can no longer integrate the individual light impulses coming from a pixel

- The refresh rate above which a picture stops flickering and fuses into a steady image is called the **critical fusion frequency** (CFF) .

- Another technique for stable image is interlacing. In this technique instead of refreshing the screen every time, the electron beam sweeps alternate lines in each pass. Odd number of lines are refreshed in first pass. In second pass, even numbered lines are drawn, this allows refresh rate to be double because only half of the screen redrawn at a time. Usual rate for interlace scanning is 87HZ so 43.5 Hz of real refresh in half screen interlacing. Odd numbered lines represent scanning one half of the screen and even numbered lines represent scanning of the other half. There are two separate sets of horizontal and vertical retrace.

- When referring to a computer monitor or another display, **interlace** or **interlacing** is a description of how the picture is created. With an interlaced display the picture is created by scanning every other line, and on the next scan, scanning every opposite line. Interlacing allows for a faster refresh rate by having less information during each scan at a lower cost. Unfortunately, this may cause flickering or noticeable line movements in some situations.

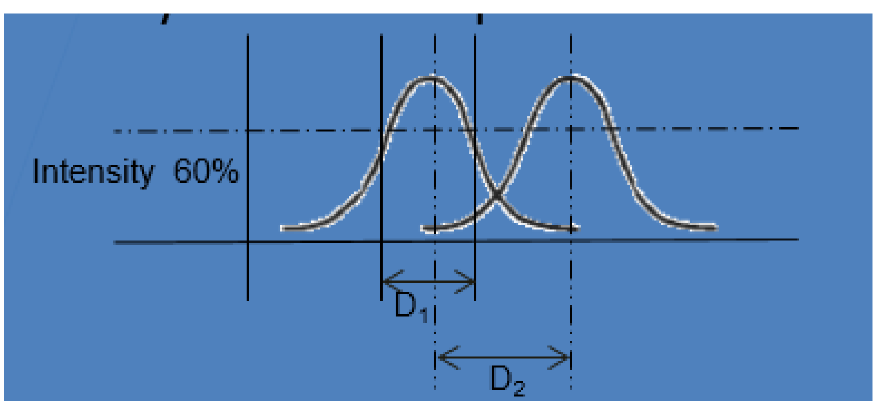
Resolution:

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

- Factors affecting the resolution are as follows

a) Spot profile:

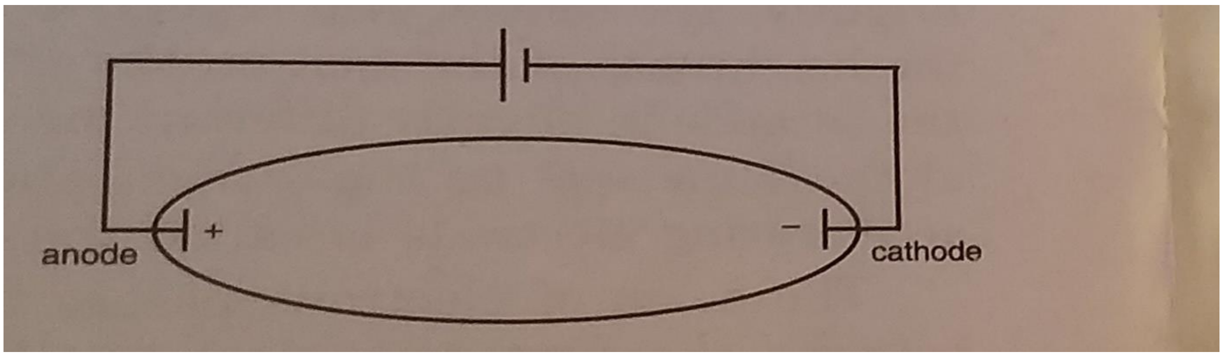
- The spot intensity has a Gaussian distribution. So two adjacent spots on the display device appear distinct as long as their separation D_2 is greater than the diameter of the spot D_1 at which each spot has an intensity of about 60 percent of that at the center of the spot



b) Intensity:

- As the intensity of the electron beam increases the spot size on the display tends to increase because of spreading of energy beyond the point of bombardment
- This phenomenon is called *blooming.* Consequently, the resolution decreases.
- Thus it is noted that resolution is not necessarily a constant and it is not necessarily equal to the resolution of a pix-map, which is allocated in a buffer memory.

CRT: A cathode ray tube is a type of analog display device, special, electronic vacuum tubes that use focused electrons beams to display images. It has a cathode or negatively charged terminal.



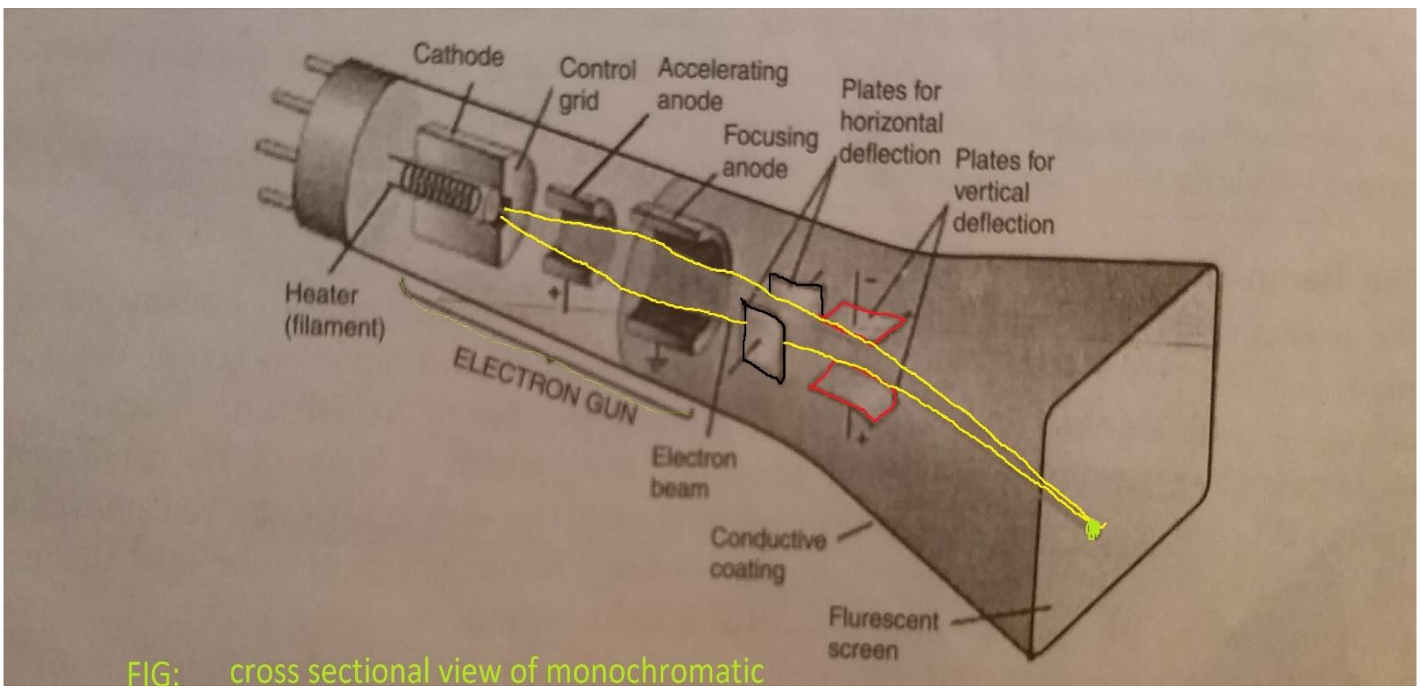


FIG: cross sectional view of monochromatic

Color CRTs

- Color depends on the light emitted by phosphor.
- Two types:

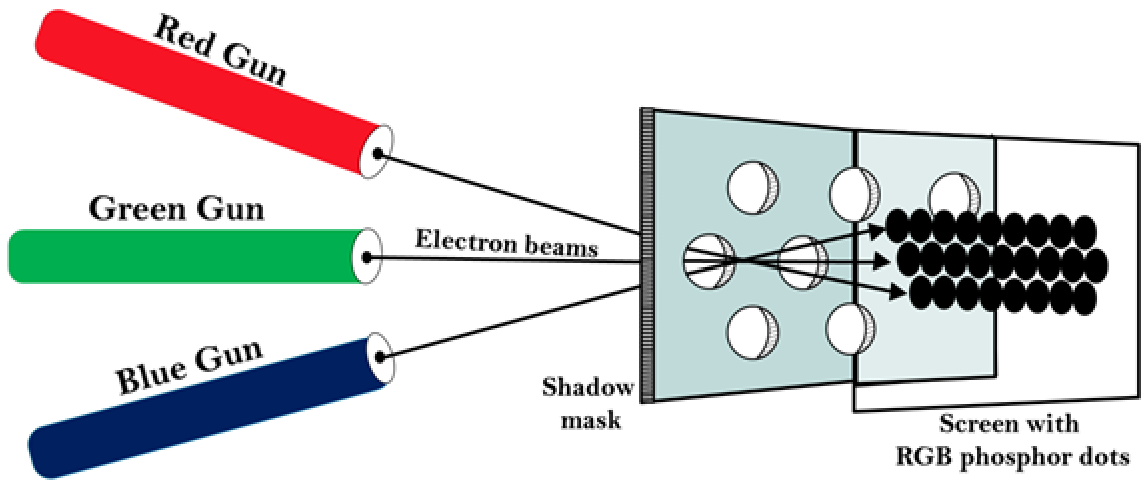
- **Beam Penetration Method**
- **Shadow Mask Method**

Beam Penetration Method:

- Two different layers of phosphor coating used Red (outer) and Green (inner)
- Display of color depends on the depth of penetration of the electron beam into the phosphor layers
- A beam of slow electrons excites only the outer red layer
- A beam of very fast electrons penetrates thru the red phosphor and excites the inner green layer
- When quantity of red is more than green then color appears as orange
- When quantity of green is more than red then color appears as yellow
- Screen color is controlled by the beam acceleration voltage.
- Only four colors possible, poor picture quality

Shadow Mask Method

- The inner side of the viewing surface of a color CRT consists of closely spaced groups of red, green and blue phosphor dots.
- Each group is called a *triad*
- A thin metal plate perforated with many small holes is mounted close to the inner side of the viewing surface. This plate is called *shadow mask*
- The shadow mask is mounted in such a way that each hole is correctly aligned with a triad in color CRT
- There are three electron guns one for each dot in a triad
- The electron beam from each gun therefore hits only the corresponding dot of a triad as the three electron beams deflect
- A triad is so small that light emanating from the individual dots is perceived by the viewer as a mixture of the three colors
- Thus, a wide range of colors can be produced by each triad depending on how strongly each individual phosphor dot in a triad is excited.



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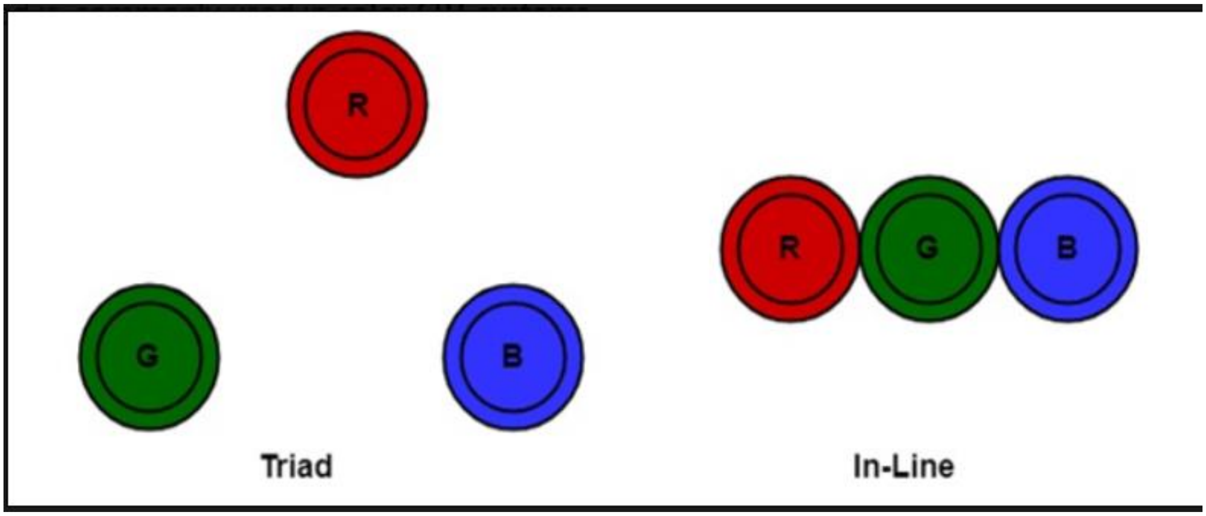
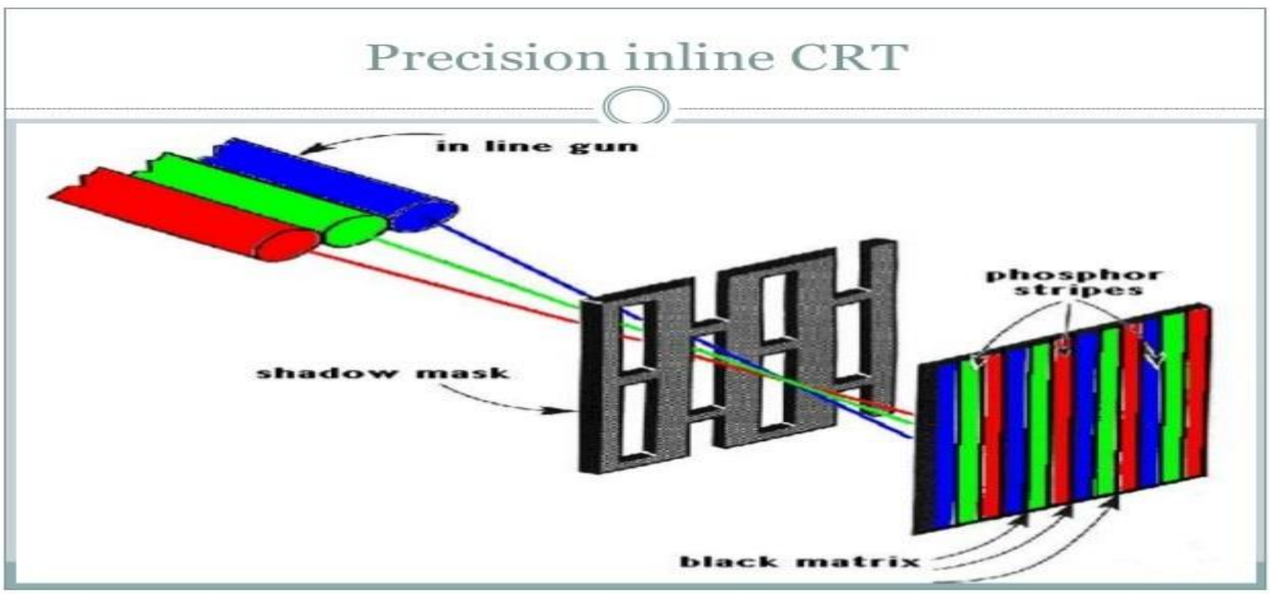
a) Delta –Delta CRT

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

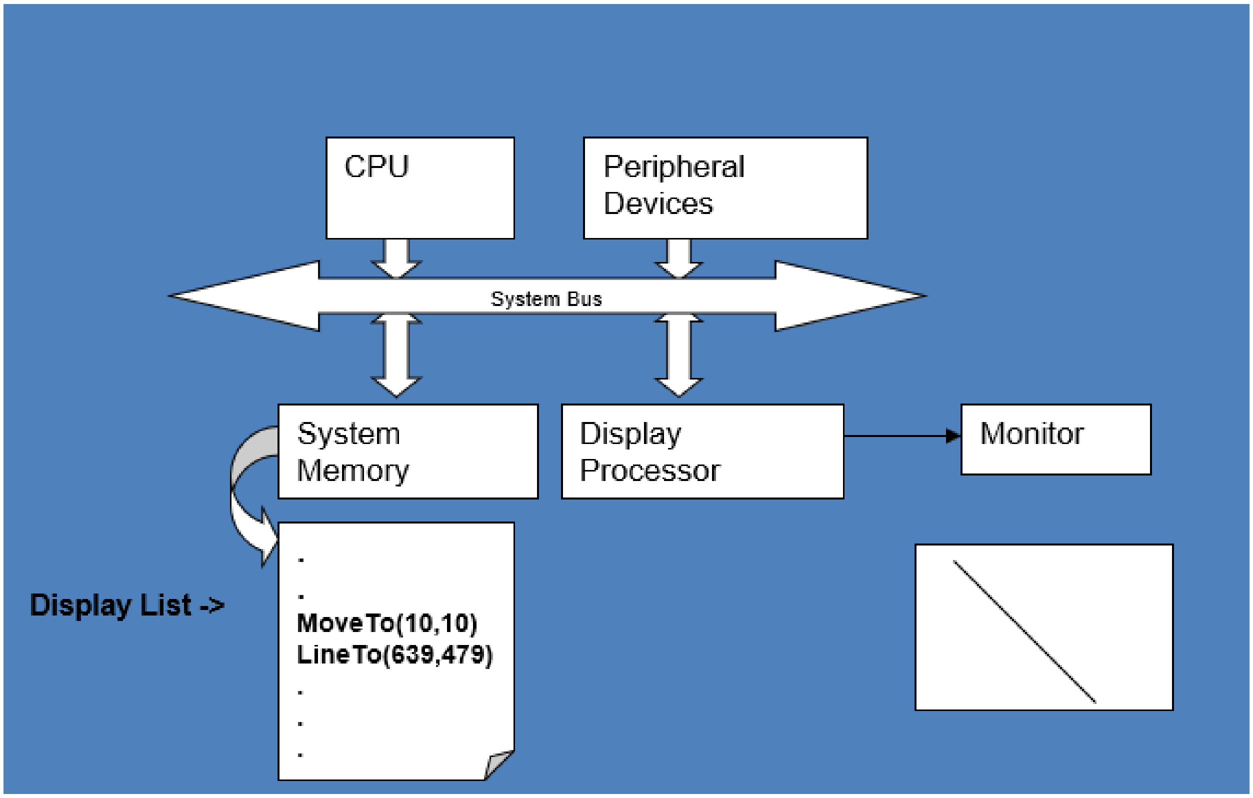
b) Precision Inline CRT

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

- 



A) Vector Display Technology



- It is also called **random scan, a stroke, a line drawing or calligraphic display**

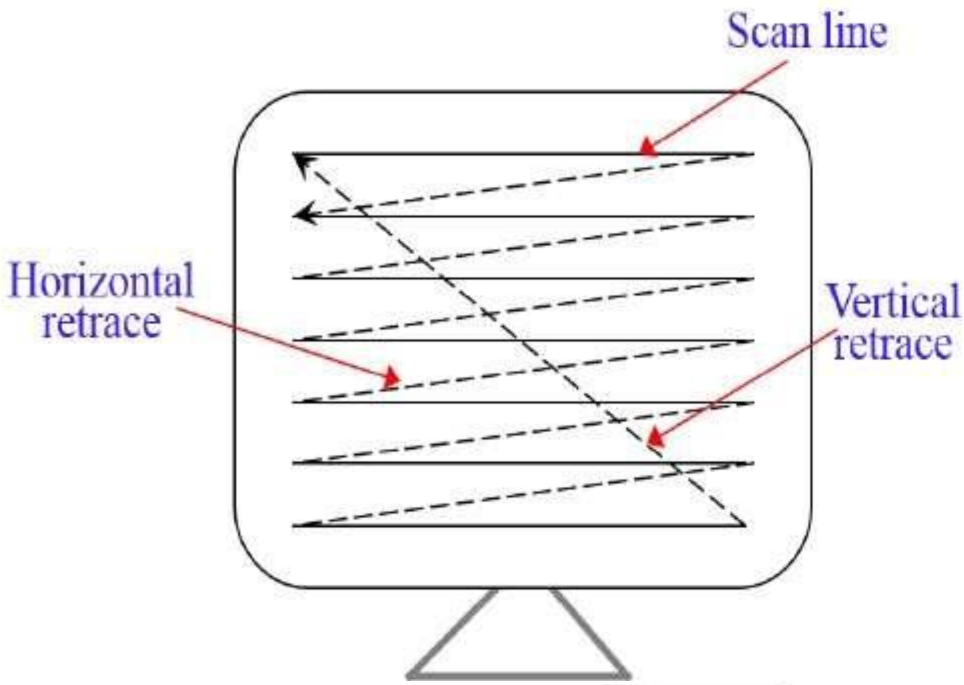
Advantages:

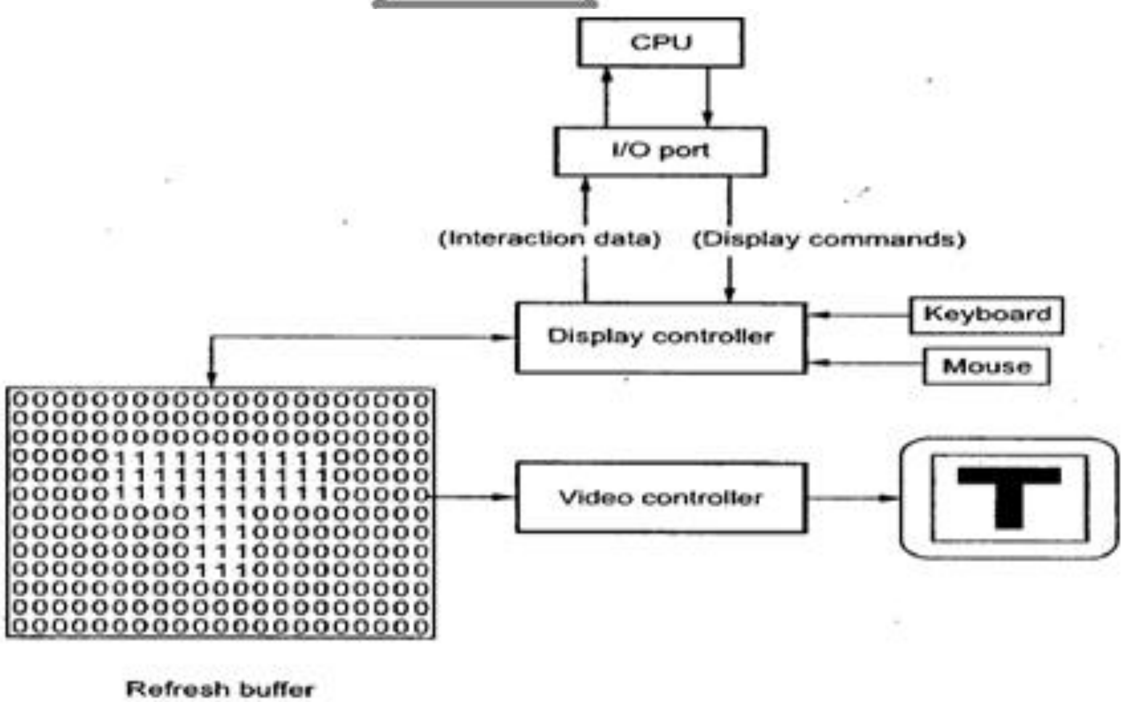
- It can produce a **smooth output primitives** with higher resolution unlike the raster display technology
- It is better than raster display for real time dynamics such as **animation**
- For transformation, only the end points has to be moved to the new position in vector display but in raster display it is necessary to move those end points and at the same time all the pixels between the end points must be scan converted using appropriate algorithm
- No prior information on pixels can be reused

Disadvantages:

- A vector display **cannot fill areas** with patterns and manipulate bits
- Time required for refreshing an image depends upon its complexity **(more the lines, longer the time)** the flicker may therefore appear as the complexity of the image increases. The fastest vector display can draw about 100000 short vectors in a refresh cycle without flickering

B) <u>Raster Display Technology</u>





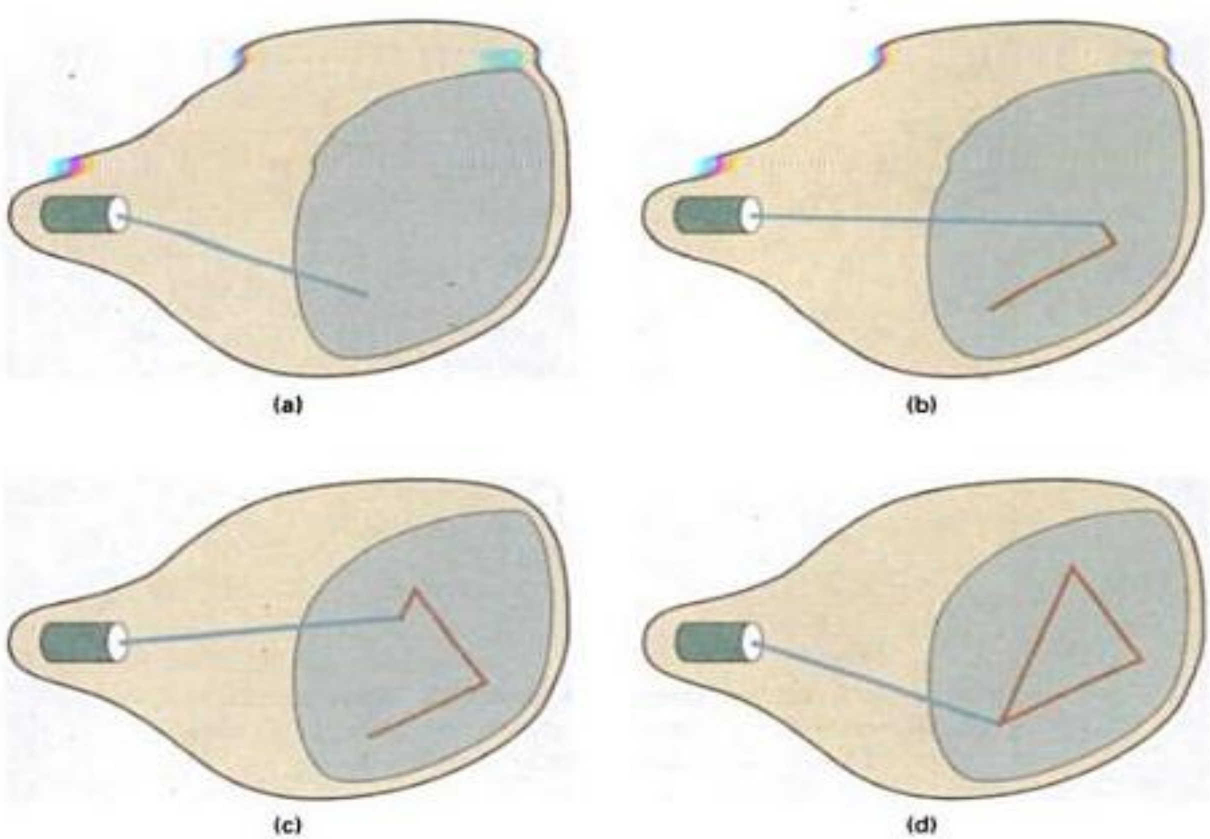
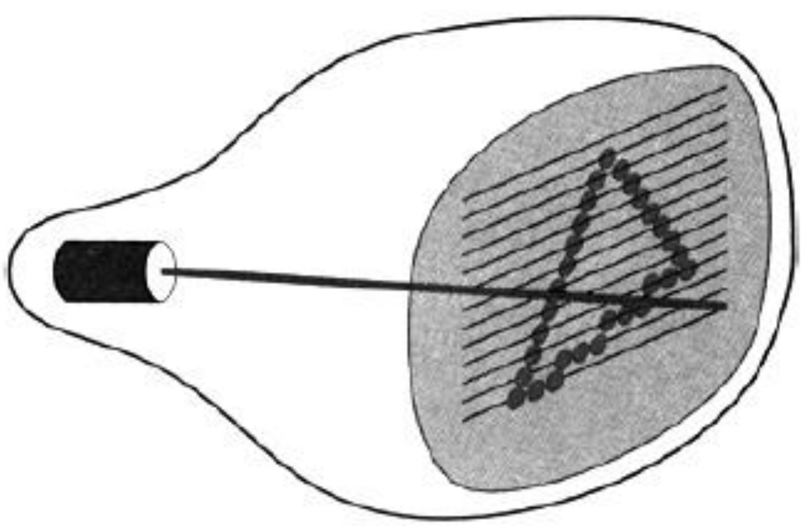


Fig: A raster scan display an object as a set of discrete points across each scan line



Advantages

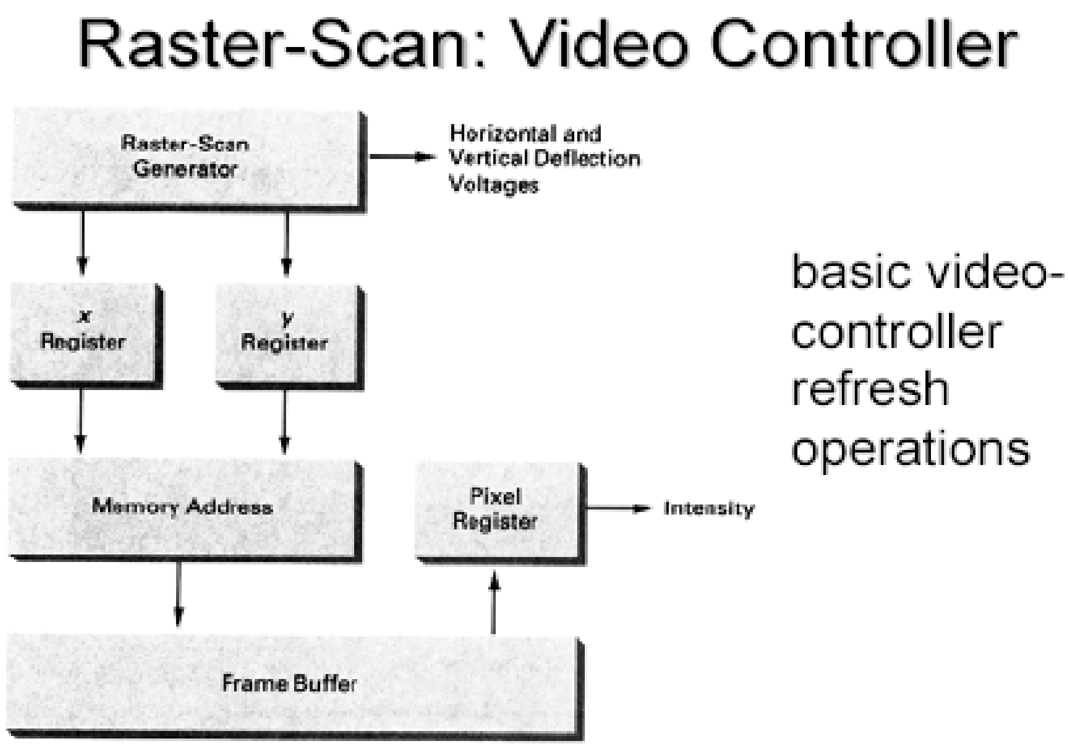
- It has an **ability to fill** the areas with solid colors or patterns

- The time required for refreshing is **independent of the complexity** of the image
- **Low cost**

Disadvantages

- For Real-Time dynamics not only the end points are required to move but all the pixels in between the moved end points have to be scan converted with appropriate algorithms which might slow down the dynamic process.

Due to scan conversion **“jaggies”** or **“stair-casing”** are unavoidable.



Two register are used to store the coordinates of the screen pixels. Initially the X register is set to 0 and Y register is set to Y_{max}. The value stored in the frame buffer for this pixel position is then retrieved and then used to set the intensity of CRT beam. Then the X register is increased by one and the process is repeated for the next pixel in the top scan line. This process is repeated for each pixel along line. When the last pixel of the top scan line has been processed, the X register is reset to zero and Y register is decremented by 1 pixels and the process is repeated for each successive scan line. After cycling through each pixel along the bottom scan line (Y=0). The video controller resets the register to first pixel position on the top scan line and the refresh process starts over.

To speed up the pixel processing, video controller can retrieve multiple pixel values from the refresh buffer on each pass. Beside these refresh operation, video controller also performs different operations like it can retrieve pixel intensity from different memory area on different refresh cycle, Video controller also contains a look up table instead of controlling CRT beam intensity directly. This provides fast mechanism for changing screen intensity values.

Random or vector scan system	Raster scan system
1) Vector displays draw lines and characters	1) Raster display can draw areas filled with colors and patterns
2) It doesn't uses interlacing	2) It uses interlacing
3) In vector display, the beam is moved between the end points of the graphics primitives.	3) In raster , the beam is moved all over the the screen on scan line at a time from top to bottom and back to top
4) Theses displays have higher resolution	4) These display have lower resolutions
5) They draw continuous and smooth lines	5) They produces zigzag lines by approximating them with pixel on the raster grid
6) Scan conversion is not required, in a random scan, only an area of the screen with a picture is displayed.	6) Scan conversion is done through entire screen
7) The refresh rate depends directly on picture complexity	7) The refresh rate is independent of picture complexity
8) It uses Beam penetration method	8) It uses shadow mask method.
9) In a random scan, it is difficult to fill the solid pattern.	9) In a raster scan, it is easy to fill the solid pattern.
10) Example of random scan is Pen Plotter	10) Example of raster scan is TV Sets.
11) Editing is easy	11) Editing is difficult
12) It stores picture definition as a set of line commands in the Refresh buffer	12) It stores picture definition as a set of intensity values of the pixels in the frame buffer in the form of 0's and 1's
13) Electron Beam is directed to only that part of screen where picture is required to be drawn, one line at a time.	13) Electron Beam is directed from top to bottom and one row at a time on screen. It is directed to whole screen.
14) In random scan, mathematical function is used for image or picture rendering. It is suitable for applications requiring polygon drawings.	14) While in which, for image or picture rendering, raster scan uses pixels. It is suitable for creating realistic scenes.
15) Refresh rate depends on the number of lines to be displayed i.e. 30 to 60 times per second.	15) Refresh rate is 60 to 80 frames per second and is independent of picture complexity.

Tablet

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

Sonic Tablet

- The sonic tablet uses sound waves to couple the stylus to microphones positioned on the periphery of the digitizing area
- An electrical spark at the tip of the stylus creates **sound bursts**.
- The position of the stylus or the coordinate values is calculated using the **delay between** when the spark occurs and when its sound arrives at each microphone
- The main advantage of sonic tablet is that it **doesn't require a dedicated working area** as the microphones can be placed on any surface to form the tablet work area
- This facilitates digitizing drawing on thick books because in an electrical tablet this is not convenient for the stylus can not get closer to the tablet surface

Resistive Tablet

- The tablet is just a piece of glass coated with a thin layer of conducting material
- When a battery powered stylus is activated at certain position it emits high frequency radio signals which induces the radio signals on conducting layer.
- The strength of the signal received at the edges of the tablet is used to calculate the position of the stylus
- Several types of tablets are transparent, and thus can be backlit for digitizing x-ray films and photographic negatives.
- The Resistive tablet can be used to digitize the objects on CRT because it can be curved to the shape of the CRT.
- The mechanism used in the electrical or sonic tablets can also be used to digitize the 3D objects

Touch Panels

- The touch panel allows the user to point at the screen directly with a finger to move the cursor around the screen or to select the icons.

a) <u>Optical Touch Panel</u>

- It uses a series of infrared **light emitting diodes (LED)** along one vertical edge and along one horizontal edge of the panel
- The opposite vertical and horizontal edges contain **photo detectors** to form a grid of invisible infrared light beams over the display area.
- Touching the screen breaks one or two vertical and horizontal light beams thereby indicating the fingers position
- The cursor is then moved to this position or the icon at this position is selected
- This is a low resolution panel which offers 10 to 50 positions in each direction

b) <u>Sonic Touch Panel</u>

- Bursts of high frequency sound waves traveling alternately horizontally and vertically are generated at the edge of the panel .
- Touching the screen causes part of each wave to be reflected back to its source
- The screen position at the point of contact is then calculated using the time elapsed between when the wave is emitted and when it arrives back at the source
- This is a high resolution touch panel having about 500 positions in each direction

c) <u>Electrical Touch Panel</u>

- It consists of slightly separated two transparent panel one coated with a thin layer of conducting material and the other with resistive material
- When the panel is touched with a finger the two plates are forced to touch at the point of contact thereby creating the voltage drop across the resistive plate which is then used to calculate the coordinate of the touched position

<u>Light pen</u>

- It is a pencil shaped device to determine the coordinates of a point on the screen where it is activated such as pressing the button .
- In raster display ‘y’ is set at y_{max} and ‘x’ changes from 0 to x_{max} the first scan line .
- For the second line ‘y’ decreases by one and ‘x’ again changes from 0 to x_{max} and so on

- When activated light pen sees a burst of light at certain position as the electron beam hits the phosphor coating at that position it generates an electric pulse
- The resolution of the touch panel is similar to that of sonic touch panel
- This is used to save the video controller's 'x' and 'y' registers and interrupt the computer
- By reading the saved valued the graphics package can determine the coordinates of the position seen by the light pen

Drawbacks

- Light pen **obscures screen images** as it is pointed to required spot
- Prolong use of it can cause **arm fatigue**
- It cannot report the coordinates of a point that is **completely black** as a remedy one can display a dark blue field in place of the regular image for a single frame time
- It gives sometimes **false reading** due to back ground lighting in a room

Graphics Software:

Graphics software is used to create images as well as processing the images to make it realistic. Interactive graphics allow users to make change over the displayed objects. Several Graphics software package are now available. There are two general classifications for graphics software

a) **General programming package**
b) **Special purpose application package**

General programming language: It contains graphics functions that can be used with high level programming language such as C, FORTRAN, JAVA etc Example OpenGL (Graphics Library). A general –purpose graphics package provides users with a variety of function for creating and manipulating pictures. These graphics functions include tools for generating picture components, setting color, selecting views and applying transformation.

Special-purpose application packages: It is specifically designed for particular applications. Maya, CINEMA 4D, paintbrush are particularly used for animation, different types of CAD applications are designed for medical and business purposes. These are primarily oriented to non-programmers.

Software Standards

GKS (Graphical Kernel System)

- GKS (Graphical Kernel System) is the international standard for two-dimensional graphics on computer systems.

- **Graphical** Kernel System, **GKS** is an international standard for computer **graphic** files that define how **graphics** are handled by software. This standardization allows for computer **graphic** files to be created on one computer and moved to a different computer or software program.
- The Graphical Kernel System (GKS) is a document produced by the International Standards Organization (ISO) which defines a common interface to interactive computer graphics for application programs.
- GKS is truly device independent
- GKS is a *kernel* system,
- However, one should point out that GKS itself is not portable.
- It provides applications programmers with standard methods ofcreating, manipulating, and displa ying or printing computer graphics on different types of computer graphics output devices.
- It provides an abstraction to save programmers from dealing withthe detailed capabilities and inte rfaces of specific hardware.
- It was the first true standard for graphics applications programmers and has been adopted by both ANSI and ISO.

  A descendant of GKS was PHIGS.
- **PHIGS**

PHIGS, the Programmer's Hierarchical Interactive Graphics System, is a programming library for 3D graphics.The PHIGS high-level graphics library contains over 400 functions ranging from simple line drawing to lighting and shading. Phigs is a standard language for graphics programming which has emerged as the successor to the previous market leader and ISO standard - GKS.

PHIGS (**Programmer's Hierarchical Interactive Graphics System**) is an API standard for rendering 3D computer graphics, at one time considered to be the 3D graphics standard for the 1990s. Instead a combination of features and power led to the rise of OpenGL, which became the most popular professional 3D API of the 1990s. PHIGS is no longer used

Limitation of PHIGS

PHIGS does not do many things necessary for photorealistic and advanced animation purposes. Among them, it does neither ray tracing nor radiosity, it doesn't compute shadows or follow light as it bounces from one object to another, and it doesn't provide texture mapping.

What PHIGS can't do

Just in case you have high hopes for PHIGS to perform wonderful graphics for you, you should know that (at least for standard PHIGS):

- It does not do ray-tracing or radiosity
- It does not compute shadows
- It does not provide texture mapping
- Motion blur or realistic fog effects are tough to do with PHIGS

PHIGS originally lacked the capability to render illuminated scenes, and was superseded by **PHIGS+**

PHIGS+

- PHIGS+ works in essentially the same manner, but added methods for lighting a 3D scene.
- PHIGS+ is an extension to PHIGS covering advanced primitives such as curves and surfaces as well as rendering , such as lighting, shading .
- It covers the basic theory of PHIGS and 3D graphics including color theory, transformations, splines and rendering, and also contains examples of how to implement practical graphics functionality such as using structure networks, creating viewing transformations and using input devices in a real application environment.

Coordinate representations

- We can construct the shape of individual objects, in a scene within separate coordinate reference frames called modeling coordinates or local coordinate.
- Once individual object shapes have been specified, we can place the object 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 called device coordinate.
- A graphics system first converts world-coordinates position 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 particular workstation
- An initial modelling-coordinates position (x_{mc}, y_{mc}) in this illustration is transferred to device coordinate position (x_{dc}, y_{dc}) with the sequence:

  $(x_{mc}, y_{mc}) \rightarrow (x_{wc}, y_{wc}) \rightarrow (x_{nc}, y_{nc}) \rightarrow (x_{dc}, y_{dc})$

Need of Machine Independent graphics language

1. Machine independent graphical language is any language that can be run by any computer without regard to its architecture or even its operating system.
2. Primary goal of standardized graphics software is portability.
3. When packages are designed with designed from one hardware often cannot be transferred to another system without extensive rewriting of the programs.

4. Thus, machine independent graphical language is required.
5. National and international standard organization in many countries has cooperated in an effort to develop generally accepted standard for computer graphics

Human Visual System:

1. Structure of human eye:

→ The eye is nearly a sphere, with an average diameter of approximately 20 mm.

→ Three membrane enclose the eye: the cornea and sclera outer cover; the choroid; and the retina.

→ The cornea is a tough, transparent tissue that covers the interior surface of the eye. Continuous with the cornea, the sclera is an opaque membrane that encloses the remainder of the optic globe.

→ The choroid lies directly below the sclera. The choroid coat is heavily pigmented and hence helps to reduce the amount of extraneous sight entering the eye and the backscatter within the optic globe. At its interior extreme, the choroid is divided into ciliary body and the iris. They contract or expand to control the amount of light that enters the eye. The central opening of the iris (the pupil) varies in diameter from approximately 2-8 mm. the front of the iris contains the visible pigment of the eye whereas the back contains the black pigment. The lens is made up of concentric layers of fibrous cells and is suspended by fibers that attach to the ciliary body. The lens is colored by as light yellow pigmentation that increases with edge.

→ The innermost membrane of the eye is the retina, which lines the inside of the wall's entire posterior portion. Light from an object outside the eye is imaged on the retina. Pattern vision is afforded by the distribution of discrete light receptors over the surface of retina. There are two classes of receptors: cones (highly sensitive to color) and rods (sensitive to low levels of illumination).

2. Image formation in the eye

→ In an ordinary photographic camera, the lens has a fixed focal length, and focusing at various distances is achieved by varying the distance between the lens and the imaging plane.

→ But, in the case of human eye, the distance between the lens and the imaging region (retina) is fixed, and the focal length needed to achieve the proper focus is obtained by varying the shape of the lens.

→ This job is done by ciliary body. The distance between the center of the lens and the retina along the visual axis is approximately 17 mm. The range of the focal lengths is approximately 14 mm to 17 mm. 17mm is the case when the eye is relaxed and focused at distances greater than about 3m.

3. **Brightness adaptation and discrimination**

→ The digital images are displayed as a discrete set of entities. Due to this, the eye's ability to discriminate between different intensity levels is an important consideration in image processing results.

→ The range of light intensity levels to which human visual system can adapt is enormous on the order of 10^{10}.

→ The current sensitivity level of the visual system is called the **brightness adaptation level.**

→ The ability of an eye to discriminate between changes and the light density at any specific adaptation level is **discrimination.**

→ The quantity $\frac{\Delta I_c}{I}$, where ΔI_c is the increment of illumination discriminable 50% of the time with background illumination I is called weber ratio. A small value of $\frac{\Delta I_c}{I}$ means that a small percentage change in intensity is discriminable. This represents "good" brightness discrimination. Conversely, a large value of $\frac{\Delta I_c}{I}$ means that a large percentage change in intensity is required and hence represents poor brightness discrimination.

Color Models: A color model is a particular representation of color that is useful for atleast one particular application. We use RGB representation it images are represented in terms of their red, green and blue components. It is combination of RGB dots that can produce simulation of continuous tone color images.

Types of color models

RGB color model

The RGB color model used in color CRT monitors. In this model RED, GREEN, BLUE are added together to get the resultant color white. Each color point within the bounds of the cube is represented as the triple (R, G, B) where value for R, G, B are assigned from 0 to 1. It is a type of additive color model as all other color are generated from these three primary colors. It uses light for generating color. It is also called additive color model as we add three color components together to form any color. Color perceived are result of transmitted light.

RGB color model has (24 bits) = 256(reds) * 256(greens) * 256(blues) = 16,777,216 possible color

The main purpose of the RGB color model is for the sensing, representation and display of images in electronic systems such as television and computers, for web graphics and it's also has been used in photography but it cannot be used for print production.

Geometrical Representation of RGB color model

It is represented as a cube unit defined on R, G and B as primary axis. Each point on this cube represents a color. The origin represents a black (0,0,0) and the vertex with coordinates (1,1,1) is white. Vertices of the cube on the axes represent primary colors and the remaining vertices represent the complementary color. The line joining black and white represents gray scale and has equal components of R, G, B. In RGB color model, the higher the values of R, G, B the brighter is the color. If R=G=B, the color will be a shade of gray.

Actually in RGB model, colors are represented by varying intensities of R,G,B light.The intensities of each R, G, B components are represented on a scale from 0 to 255 RGB color model and CMY color model are complementary to each other.

In matrix form

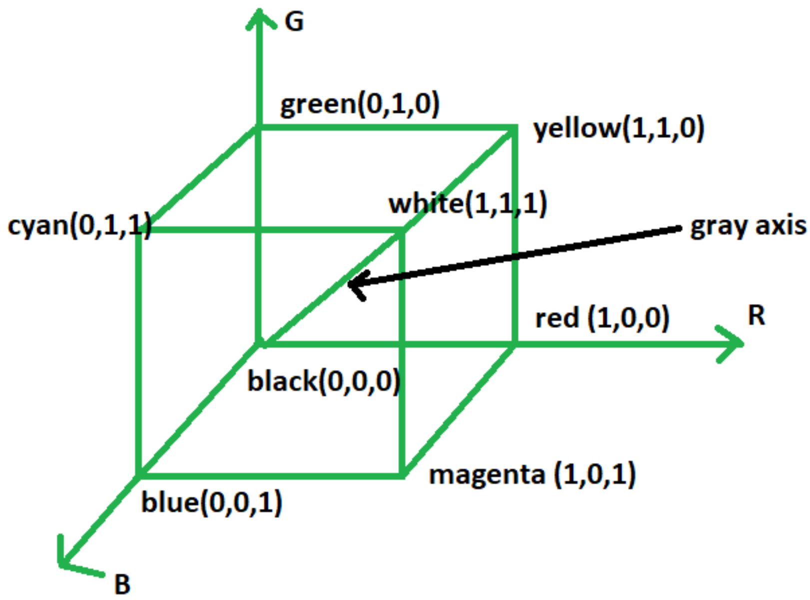
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}$$

0 – least intensity (no light emitted)

255 – Maximum intensity

127 – Half intensity

Therefore (0, 0, 0) is the darkest black color and (255,255,255) is the brightest white color



HSV color model:

The HSV color model attempts to characterize colors according to their hue, saturation, and value (brightness). HSV is derived from the RGB model. The HSV color space is widely used to generate high quality computer graphics or is used to select various different colors needed for a particular picture. The hue is color portions of the color model and is expressed as a number from 0 to 360 degrees. The saturation is the amount of gray in the color from 0 to 100 percent. The saturation of a color identifies how pure or intense the color is. The value works in conjunction with saturation and describes the brightness or intensity of the maximum of RGB components of the color from 0-1 where 0 is completely black and 1 is the brightness and reveals the most color. The hue –Saturation-Value model is oriented towards the users.

Geometrical structure of HSV color model:

It is the polar coordinate representation of RGB color model. It has Hex-cone like geometrical structure. Hex cone origin (apex) represents black. Vertical axis represents value V through the center of hexagon, varies from 0 at the apex to 1 at the top. Saturation s is measured along horizontal axis which varies from 0 to 1. S for this model is the ratio of purity at 1. Hex cone boundary represents various hues. The hue is represented as an angle about the vertical axis ranging from 0 degree at red through 360 degree. Vertices of hex cone are separated by 60 degree interval.

1. The outer edge of the top of the cone is the color wheel, with all the pure colors. The H parameter describes the angle around the wheel.

2. The S (saturation) is zero for any color on the axis of the cone; the center of the top circle is white. An increase in the value of S corresponds to a movement away from the axis.

3. The V (value or lightness) is zero for black and white when, V=1. An increase in the value of V corresponds to a movement away from black and towards the top of the cone, with the color having maximum intensity

4. When V=1 and S=1, we have the “pure” hues V, white is the point at V=1 and S=0.

The following points may be noted from figure below:

1) The hue (H) is given by the angle about the vertical axis with red at 0^{o}, yellow at 60^{0}, green at 120^{o}, cyan at 180^{o} blue at 240^{o} and magenta at 300^{o}. Here the complementary colors are 180^{o} apart. The complementary colors are diagonally opposite. i.e (red + cyan), (blue + yellow), (green + magenta).

2. The vertical axis is called as value (V) where 0.0<V<1.0. At V=0, we have black and at V=1, we have white.

3. The horizontal axis represents saturation(S) where 0.0<=S<=1.0. It gives the purity of the color or the amount of color used and is the ratio of purity of a related hue due to its maximum purity at S=1 and V=1. At S=0 we have gray scale i.e., the diagonal of the RGB cube corresponds to V of the HSV hex cone.

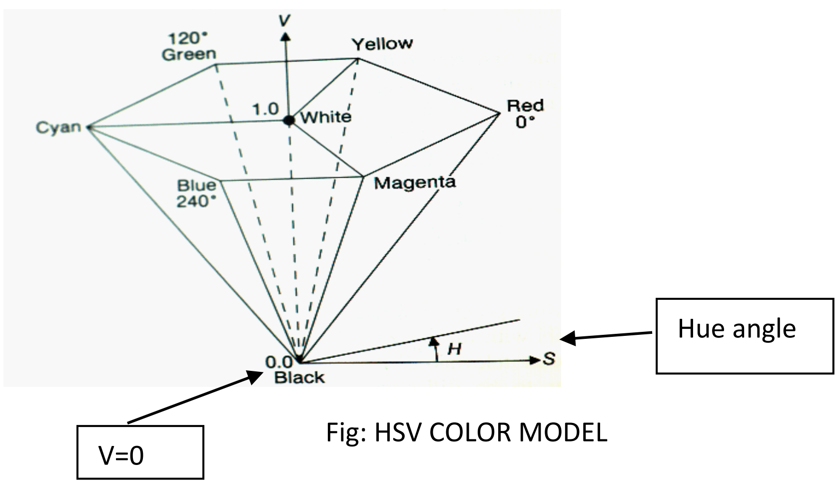


Fig: HSV COLOR MODEL

At S=V=1, we have pure hue.

To add black, decrease V and to add white decrease S. To add black and white, decrease V and S.

For example

For pure green, H = 120°, S = V = 1

For Dark green, H = 120°, S = 1, V = 0.40

For Light green, H = 120°, S = 0.3, V = 1.0

We start with a pure color or hue and then add black pigment to produce different shades. **Please understand that the more is the black pigment, the darker is the shade** We may add white pigment and get different tints. **Also note that adding both black and white pigments gives different tones**. We can show this with the help of a SV – graph also, as in fig. 13.14.

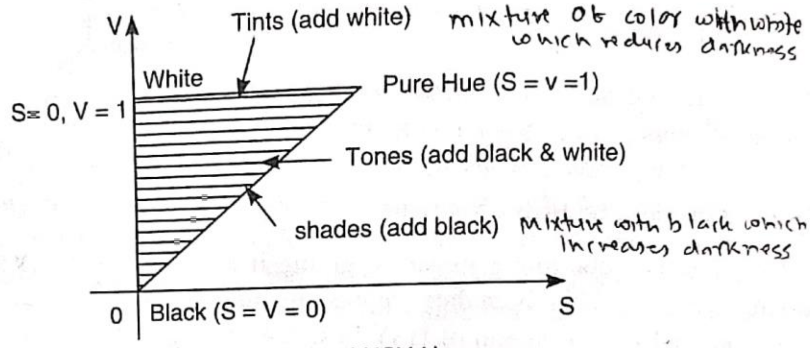


Fig. 13.14. Cross Section of HSV Hexcone

This cross section of the plane of HSV hexagon represents the terms tints, shades and tones.

Adding white produces pure tones of different tints across top of the plane where V = 1 and $0 \le S \le 1$. Various tones are specified by adding both black and white producing color points within the triangular cross – sectional area of the hexagon.

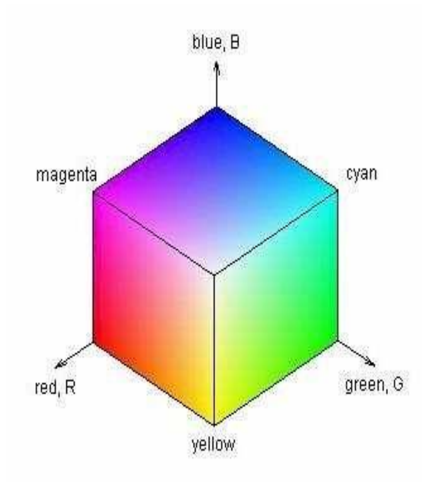
A human eye can differentiate between 128 hues, 130 tints and 23 shades.

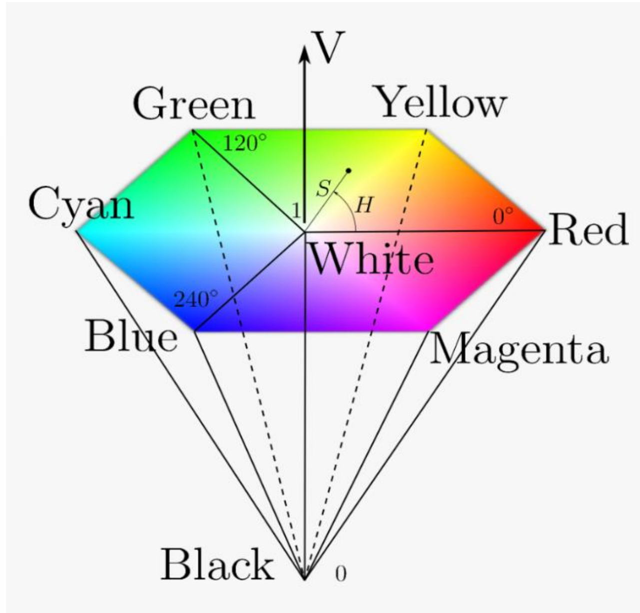
∴ We can differentiate between 128 × 130 × 23 = 380,000 different colors, For graphics application 128 hues and 8 saturation levels with 15 value settings are enough. For such a setting 14 bit of color storage per pixel is enough for a system to run an application using HSV color available to a user.

Conversion between HSV and RGB color models

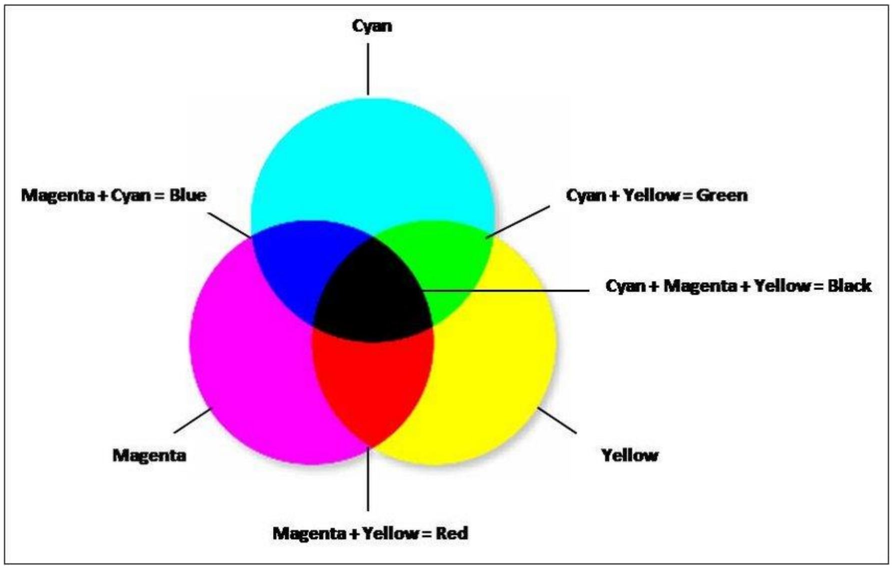
If HSV colors parameters are made available to a user of graphics package, these parameters are transformed to RGB setting needed in this transformation, we first consider how the HSV hex cone corresponds to the projection seen by looking along the principal diagonal of the RGB color cube from white towards black as shown in the figure.

Each sub cube when viewed along its main diagonal is like the hexagon in figure except smaller. Each plane of constant V in HSV space corresponds to such a view of a tube in RGB space. Each diagonal of RGB space become the V exists of HSV space. Thus we can see intuitively the corresponding between RGB and HSV.





<u>CMY and CMYK color model:</u> It is a printing method used as a four- color process. CMYK is short for Cyan, magenta, yellow, and key or ink or black which is subtractive color model. It is known as process or substrate model. The colors of an object are seen when pigments in the object absorb certain wavelength of white light while reflecting the rest. This model works by partially or entirely masking certain colors on the typically white background ie absorbing particular wavelength of light. It is a subtractive model because inks “subtract” brightness from white. In CMYK model, white is the natural color of paper or other background while black results from a full combination of colored inks (Cyan, magenta, yellow ink) – in theory. But because of impurities in ink, when CMY inks are combined, it produces a muddy brown color and this black ink is added to this system to compensate for these impurities. So to provide genuine black, printers add black ink which is known as K ie CMYK model. All of the colors in the printable portion of the color spectrum can be achieved by overlapping "tints" of cyan, magenta, yellow and black inks. A tint is a screen of tiny dots appearing as a percentage of a solid color. When various tints of the four colors are printed in overlapping patterns it gives the illusion of continuous tones - like a photograph:



In the CMYK color model, colors are represented as percentages of cyan, magenta, yellow and black. For example in the above CMYK chart the red color is composed of 14% cyan, 100% magenta, 99% yellow and 3% black. White would be 0% cyan, 0% magenta, 0% yellow and 0% black (a total absence of ink on white paper).

It is used for printing material. It uses ink to display color. It is useful for describing color output to hard copy devices

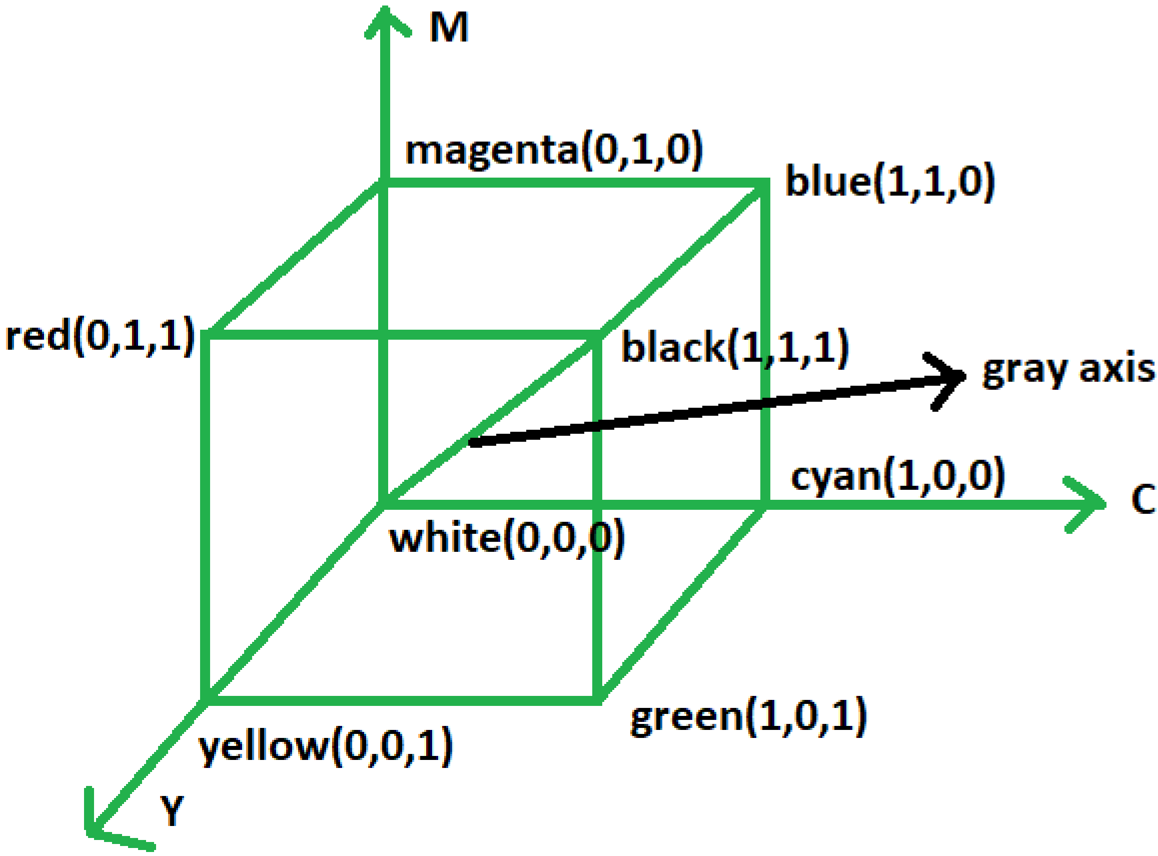
Cyan+ Magenta+ yellow = Black

Cyan if formed by adding blue and green light, when white light is reflected from cyan colored ink C = W – R ie red light is absorb by the ink, the reflected light must have no red components so C is sometime called as –R it minus Red

Magenta if formed by adding red and blue light, when white light is reflected magenta colored ink M = W – G ie green light is absorb by the ink, the reflected light must have no green components so C is sometime called as –G it minus Green.

Yellow if formed by adding red and green light, when white light is reflected from yellow colored ink Y = W – B ie blue light is absorb by the ink, the reflected light must have no blue components so C is sometime called as –B it minus Blue.

$$\begin{Bmatrix} C \\ M \\ Y \end{Bmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{Bmatrix} R \\ G \\ B \end{Bmatrix}$$



Difference between RGB and CMY color model

RBG color model	CMY color model
1) It is an additive color model	It is an subtractive color model
2) It is used for computer display and web graphics	It is used for printing material
3) It uses light for display color	It uses ink to display color
4) Color results from transmitted light	Color result from reflected light
5) Red + Green + Blue = White	Cyan + Magenta + yellow = Black