→ By William Fetter (1960)

Date. _____
Page No. _____

Graphics Primitives :-

Computer graphics is an art of drawing pictures on computer screens with the help of programming. It involves computations, creation, and manipulation of data. In other words, we can say that computer graphics is a rendering tool for the generation and manipulation of images.

What is computer Graphics ? (Visual Form)

Computer graphics is an art of drawing pictures, lines, charts, etc. using computers with the help of programming. Computer graphics image is made up of number of pixels. Pixels is the smallest addressable graphical unit represented on the computer screen.

Date. _____
Page No. _____

- Graphical objects convey more information in less time and easily understandable formats for example statically graph shown in stock exchange.

- In computer graphics picture or graphics objects are presented as a collection of discrete pixels.

- We can control intensity and color of pixel which decide how picture look like.

- The special procedure determines which pixel will provide the best approximation to the desired picture or graphics object this process is known as Rasterization.

- The process of representing continuous picture or graphic object as a collection of discrete pixels is called Scan Conversion.

Date.
Page No.

Advantages

- It provides tools for producing picture of "real-world" as well as synthetic objects such as mathematical surfaces in 4D and of data that have no inherent geometry such as survey result.
- It has ability to show moving pictures thus possible to produce animations with computer graphics.
- With the use of computer graphics we can control the animation by adjusting the speed, portion of picture in view the amount of detail shown and so on.
- It provides tools called motion dynamics In which user can move objects as well as observes as per requirement for example walk throw made by builder to show flat interior and surrounding.

Date.
Page No.

Q.8 Consider a ~~rast~~ two raster systems with the resolutions of 640 X 480 and 1280 X 1024.

a) How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second?

sol^n Since 60 frames are refreshed per second and each consists of 640 X 480 pixels, the access ratio of such a system is (640 X 480) * 60 = 1.8432 X 10^7 pixels/s

min (1280 X 1024) * 60 = 7.86432 X 10^7 pixels/s

b) What is access time per pixel in each system?

⇒ According to the definition access rate, the access time per pixel should be 1/(access rate)

Therefore, the access time is around 54 nanoseconds/pixel for 640 X 480 system, and access time is around 12.7 nanoseconds/pixels for the 1280 X 1024 system

Date.
Page No.

Q.7 Consider three different raster systems with resolutions of 640 X 480, 1280 X 1024 and 2560 X 2048

1. What size is frame buffer (in bytes) is required for each of these systems to store 12 bits/pixel?

Sol^n Because eight bits constitute a byte.

640 X 480 X 12 bits / 8 = 450 KB

1280 X 1024 X 12 bits / 8 = 1920 KB

2560 X 2048 X 12 bits / 8 = 7680 KB

2. How much storage (in bytes) is required for each if 24 bits per pixel are to be stored?

Sol^n Similarly, each of the above results is just doubled for 24 (12 x 2) bits of storage per pixel.

$d_1 = 2dy - dx$
$= 12 - 7 = 5 \ (di \geq 0)$ case 1

Date.

Page No. 12

(10,12)	$d_4 = -1$	(11,13)	$d_5 = -1+12$ $= 11$
(11,13)	$d_5 = 11$	(12,14)	$d_6 = 11+12-14$ $= 9$
(12,14)	$d_6 = 9$	(13,15)	$d_7 = 9-2$ $= 7$
(13,15)	$d_7 = 7$	(14,15)	$d_8 = 7-2$ $= 5$

$\therefore$

Date.
Page No.

and new decision parameter is

$d_i < 0$

$$d_{i+1} = d_i + 2dy$$
$$x = x + 1,$$
$$y_{i+1} = y_i$$

Initial value of decision parameter $\{ d_1 = 2dy - 2dx \}$

Ques ~~(7,9) & (14,15)~~

Consider a line (7,9) to (14,15).
Digitize a line segment.

$$m = \frac{dy}{dx} = \frac{6}{7} = 0.85 < 1$$

Previous Pixel	Decision Parameter	Next Pixel	New decision Parameter
(7,9)	$d_1 = 5$	$x = 7+1 = 8$ $y = 9+1 = 10$ (8,10)	$d_2 = 5 + 2\times6 - 14$ $= 3$
(8,10)	$d_2 = 3$	(9,11)	$d_3 = 3 + 12 - 14$ $= 1$
(9,11)	$d_3 = 1$	(10,12)	$d_4 = 1 + 12 - 14$ $= -1$

(10,12)
(11,13)
(12,14)
(13,15

1AB Q1 Im
all
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Date.
Page No.

then x is implemented by 1 & y remains same.

- Top pixel pixel is choosen then x is implemented by 1 & y also implemented by 1

The algorithm calculates decission parameter which is calculated at each iteration as follows:

Case 1:- If the choosen pixel is the top pixel than the decission parameter value is greater than equal to zero & pixel value of y changes by 1 and the new decission parameter is also calculated.

<1 (upper half)

$$\begin{cases} y_{i+1} = y_i + 1 \\ d_{i+1} = d_i + 2dy - 2dx \end{cases}$$

Case 2 : If the choosen pixel is bottom pixel than the value of decission parameter is less than zero & change in y is zero

Pixel → Physical

Date
Page No.

BRESENHAM LINE ALGORITHM

In this algorithm the next pixel which is at the least distance from a true line is selected.
The method works as follows :-

Assume a pixel given (x_1, y_1) then select subsequent pixel will be till we reached pixel E2 (x_2, y_2) the next pixel can be

(i) Either the one to the right (lower bound for the line)
(ii) One top of its right (upper bound of the line).

The line is best approximated by those pixels that are at the least ~~b~~ distance from the path b/w P1 & P2

To choose the next pixel b/w the bottom and top pixel
(i) The bottom pixel is choosen

$m < 1$ (up

$m < 1 \Rightarrow$ $P < 0$

$x = x+1$

$y =$ no change

$d_1 = d_0 + 2dy$

$P \geq 0$

$x = x+1$

$y = y+1$

$d_1 = d_0 + 2dy - 2dx$

Date

Page No.

BRESENHAMS ALGORITHM

(i) Plot initial point

(ii) Find Δx, Δy, $2\Delta y$, $2\Delta y - 2\Delta x$

(iii) Where

(a) $\Delta x = |x_2 - x_1|$ & $\Delta y = |y_2 - y_1|$

$m = \frac{\Delta y}{\Delta x}$

(iii) Calculate $\boxed{d_0 = 2\Delta y - \Delta x}$

(iv) Start at iteration $k = 0$, at each x_k do this

(a) if $d_k < 0$

Plot (x_{k+1}, y_k)

$d_{k+1} = d_k + 2\Delta y$

(b) if $d_k \geq 0$

plot (x_{k+1}, y_{k+1})

$d_{k+1} = d_k + 2\Delta y - 2\Delta x$

(v) Repeat step (iv) Δx no. of times (0 to $\Delta x - 1$) iteration

$\Rightarrow m \geq 1$

$P < 0$

$y = y+1$

$d_1 = d_0 + 2dx$

$x = x$

$P \geq 0$

$x = x+1$

$y = y+1$

$d_1 = d_0 + 2dy - 2dx$

$|\Delta y| > |\Delta x|$

No. of steps $\Delta Y = 6$

$M > 1$ (Case 3)

Now, step 3 is executed until step 4 is satisfied.

X_p	Y_p	$(1/M + X_p)$ X_{p+1}	$(1 + Y_p)$ Y_{p+1}	Round off (X_{p+1}, Y_{p+1})
5	6	5.5	7	6, 7
5.5	7	6	8	6, 8
6	8	6.5	9	7, 9
6.5	9	7	10	7, 10
7	10	7.5	11	8, 11
7.5	11	7.5	12	8, 12

No. of steps = 6

Imp

Advantages:-

- It is simple algorithm
- It is easy to implement.
- It avoids using the multiplication operation ~~ope~~ which is costly in terms of time complexity.

Disadvantages:-

- There is an extra overhead of using round off() function.
- ~~There is an extra overhead of~~
- Using round off() function increases time complexity of the algorithm
- Resulted lines are not smooth because of round off() function.
- The points generated by this algorithm are not accurate.
- It is more suitable for generating line using the software. But it is less suited for hardware implementation

Step 1:-
- Starting coordinates Calculate $\Delta x, \Delta y$
- These parameters are calculated as:-
- $\Delta x = x_n - x_0$, $\Delta y = y_n - y_0$
- $m = \Delta y / \Delta x$

Step-2:-
- Find the number of steps or points in b/w the starting and ending coordinates.
- If absolute (Δx) > absolute (Δy) (always +ve)
  steps = absolute (Δx);
  else
  steps = absolute (Δy);

Step-3:-
- Suppose the current point is (x_p, y_p) and the next point is (x_{p+1}, y_{p+1})
- Find the next point by following below three cases:-

Three Cases:

Case 1:- If $m < 1$	x_{p+1} = round off $(1 + x_p)$	y_{p+1} = round off $(m + y_p)$
Case 2:- If $m = 1$	x_{p+1} = round off $(1 + x_p)$	y_{p+1} = round off $(1 + y_p)$
Case 3:- If $m > 1$	x_{p+1} = round off $(1/m + x_p)$	y_{p+1} = round off $(1 + y_p)$

Step 4:-
Keep repeating step 3 until the end point is reached or the number of generated new points (including the starting and ending points) equal to the steps count.

Q.1 Calculate the points b/w the starting (5,6) and ending point (8,12).

Given - $(x_0, y_0) = (5,6)$
$(x_n, y_n) = (8,12)$

$\Delta x = x_n - x_0 = 8 - 5 = 3$
$\Delta Y = Y_n - Y_0 = 12 - 6 = 6$
$m = \Delta Y / \Delta x = 6/3 = 2$

Date.
Page No.

Line Drawing Algorithms
- → DDA Drawing Algorithm
- → Bresenham Line Drawing Algorithm
- → Mid point Line Drawing Algorithm

DDA :- Digital Differential Analyzer

- It is a scan conversion method for drawing a line.
- It follows the incremental approach.
- Difference in pixel point is to be analysed.

Procedure -
Given,
Starting coordinates = (x_0, y_0)
Ending Coordinates = (x_n, y_n)
The points generation using DDA algorithm involves following steps:-

Date
Page No.

Used

- Used when project involves physically printed designs etc. such as business card, poster or a newsletter.
- Used in cloth branding like t-shirt
- Advertising like billboards, flyers

Impact Printers

Impact printers are printers which works by creating a direct contact b/w ink ribbon and paper. It has mechanical moving parts to conduct printing.

Non-Impact Printers

Don't uses any direct contact b/w ink ribbon and papers. They use laser, xerographic, electrostatic, chemical or inkjet technology

Impact Printer	Non Impact Printer
• Produces characters and graphics on a piece of paper by striking	A type of printer that produces chars and graphics on a piece of paper with striking
• It prints by hammering a set of metal pins or character set.	Printing is done by depositing ink in any form. Not
• Electromechanical devices are used.	
• Faster speed around 250 words/sec.	Slower speeds arou -nd 1 page/30 sec. Works silently
• Have banging noise of needle on paper	
• Ex: Dot-matrix, Daisy wheel, line printers.	Inkjet, photo, laser printers
• It generally cost less	It cost more
• Not suited for printing, photography or any high quality media.	Best suited for printing, photogra -phy,

PPI (Pixels Per Inch) : is the measure of resolution in a digital image or video display. It measures the display resolution, pixel density, of a computer monitor on screen.

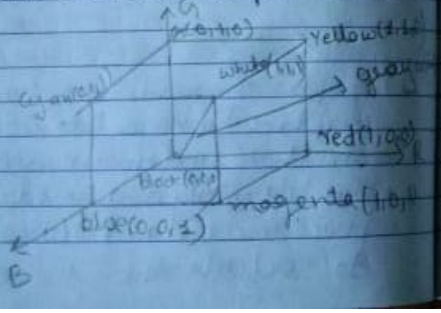
Date
Page No.

Difference b/w RGB and CMYK Color Sc

Both RGB and CMYK are color schemes used for mixing color in graphic desi

1. The RGB Color Model → .jpeg, .png, .gif

The RGB color model is one of the most widely used color representation method in computer graphics. It use color coordinate system with three primary colors:
R (red), G (green), B (blue)
Each primary color can take an intensity value ranging from 0 (lowest) to 1 (highest). Mixing of all colors obtained by such a linear combination of red, green & blue forms the cube shaped RGB color space.



Date
Page No.

Color specification using the RGB model is an additive process. We begin with black & add on the appropriate primary components to yield a desired color.

⇒ Uses
- Used when project involves digital screens like computers, mobile, TV etc.
- Used in web and application design
- Used in online branding
- Used in social media, online logos, ads.

Cyan magenta Yellow key (Black)

2. CMYK Color Scheme:

It is the color scheme used for projects including printed materials.
This color scheme is a subtractive type mode that combines the colors - cyan, magenta, yellow and black in various degrees which creates a variety of different colours.
A printing machine creates images by combining these colors with physical link. When all colours are mixed with 0% degree white color is created CMYK(0,0,0,0)
→ File format : PDF, EPS etc

Date.
Page No.

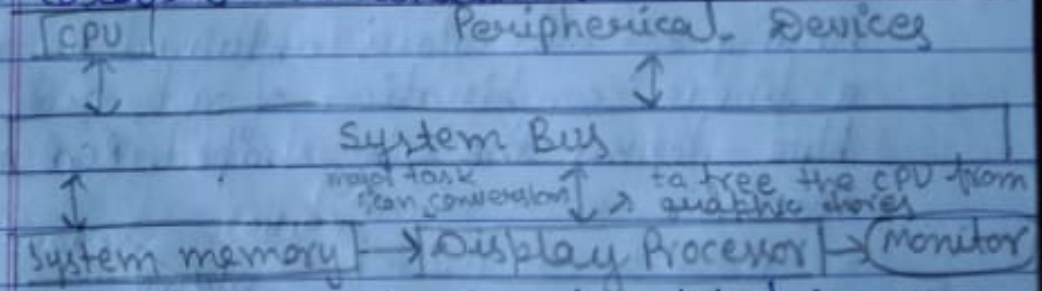
Random-Scan Display:-

Advantages:—

- Random scan displays have higher resolution than raster systems.
- Vector displays product smooth line drawing.
- This minimal amount of information translates to a much smaller file size
- On zooming in, and it remains smooth
- The parameters of object are stored and can be later modified.

Disadvantages:—

- Random-scan monitors cannot display realistic shades scenes.
- Colour limitations.



- Graphic commands are translated by the graphics package into a display file stored in the system memory.
- This file is then accessed by the display processor unit (DPU) (graphic controller) to refresh the screen.

Date
Page No.

- The quality of a raster image is determined by the total number pixels (resolution), and the amount of information in each pixel (color depth)
- A black-and-white system is each screen point is either on or off, so only one bit per pixel is needed to control the intensity of screen positions. Such type of frame buffer is called bit map.
- High quality raster graphics system have 24 bits per pixel in the frame buffer (a full color system or a true color system).
- Refreshing on raster scan display is carried out at the rate 60 to 80 frame per second.

Date
Page No.

INTERLACING

- On some raster systems (TV), each frame is displayed in two passes using an interlaced refresh procedure.
- Interlacing is primarily used for slower refresh rates.
- An effective technique to avoid flicker (Flicker occurs on CRT's when they are driven at a low refresh rate, allowing the brightness to drop for time intervals sufficiently long to be noticed by a human eye).

APPLICATIONS

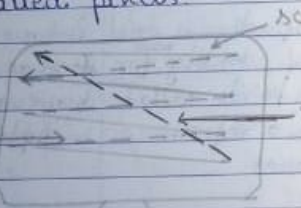
- Suited for realistic display on screens.
- Home television computer printers create their images basically by raster scanning. Laser printers use a spinning polygonal mirror (or an optical equivalent) to scan across the photosensitive drum, and paper movement provides the other scan axis.

Date.
Page No.

RASTER SCAN DISPLAY

Raster : A rectangular array of points or dot.

- An image is subdivided into a sequence of (usually horizontal) strips known as "scan lines" which can be further divided into discrete pixels for processing in a computer system.
- A raster image is a collection of dots called pixels



Working :-

- In a raster scan system, the electron beam is swept across the screen, one row at a time from top to bottom.

Date.
Page No.

- As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.
- The return to the left of the screen, after refreshing each scan line is called Horizontal retrace.
- At the end of each frame the electron beam returns to the top left corner of the screen to begin the next frame is called Vertical retrace
- Picture definition is stored in a memory area called the refresh buffer or frame buffer.
- Refresh buffer or frame buffer is memory area that holds the set of intensity values for all the screen points.
- Stored intensity values then retrieved from refresh buffer and "painted" on the screen one row (scan line) at a time.

After all lines drawing commands have been processed, the system cycle back to the first line command in the list.

in an area of memory called the Refresh Display File.

↓

also called Refresh Buffer

Refresh Rate?

- It depends on the number of lines to be displayed.
- The refresh rate of random scan display is 30 to 60 frames per second.

Example?

If we want to display and maintain a picture of a triangle ABC on the screen then the display list will have command like this,

1. Draw a line from A to B
2. Draw a line from B to C
3. Draw a line from C to A

* To display a specified picture, the system cycles through the set of commands in the display file and drawing each component line in a turn.

	Raster Scan Display	Random Scan Display
Electron Beam	The electron beam is swept across the screen, one row at a time, from top to bottom.	The electron beam is directed only to the parts of screen where a picture is to be drawn.
	Its resolution is poor bcz raster system is contrast produces zigzag lines that are plotted as discrete point sets	Its resolution is good bcz this system produces smooth lines drawings because CRT beam directly follows the line path
	Picture definition is stored as a set of intensity values for all screen points called pixels in a refresh buffer area	Picture definition is stored as a set of line drawing instructions in display file
	Screen points/pixels are used to draw an image	Mathematical functions are used to draw an image

Date.
Page No.

Persistence ?

- Persistence is defined as the time it takes the emitted light from the screen to decay to one tenth of its original intensity. Lower-persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker.
- Graphics monitors are usually constructed with a persistence in the range from 10 to 60 microseconds.

Resolution

- A max number of points that can be displayed without overlap on CRT
- Typically 1028X1024
- The resolution is defined as the number of pixels (individual points of color) contained on a display monitor, expressed in terms of the no. of pixels on the horizontal axis & the no. on the vertical axis.

Date.
Page No.

- The sharpness of the image on a display depends on the resolution and the size of monitor.
- Higher the resolution, better the graphics system.

There are two ways (Random scan and Raster scan) by which we can display an object on the screen.

Random Scan Displays

- In random scan display the electron beam is directed to the area on screen only where the picture is to be drawn.
- Random scan display are also known as vector display.
- The reason it also called vector display is because random scan display draws the picture one line at a time.

Refresh Display File ?

The picture definition is stored as a set of line drawing commands

= width / height

Date
Page No.

What is Aspect Ratio in a Computer Graphics?

The Aspect Ratio of an image or any device is the ratio of its width to its height. ex: 16:9
width → height

Used to determine the relative horizontal and vertical sizes of computer graphics.

Various Kinds of Aspect Ratios –

1:1 (square) Standard - are rarely utilized in gadgets and screens. The square video is was promoted by versatile applications, for ex, Instagram, facebook and twitter.

4:3 Standard - (1.3:1) has been used for TVs.

16:10 Standard - generally utilized for PC presentations and tablet PCs. Width of presentation is 1.6 times its height.

Date
Page No.

16:9 (1.78:1) is universal standard configuration of HDTV, non-HD computerized TV, and simple widescreen TV.

1.85:1 Standard - a common widescreen for movies especially in Hollywood.

2:1 standard "Univision" It was compromise, designed to make everyone's life easier; to produce image that would need only minimal letterboxing

2.35:1 & 2.39:1 'Anamorphic' format is the cinematography technique of shooting a widescreen picture on standard 35mm film or other visual recording media with

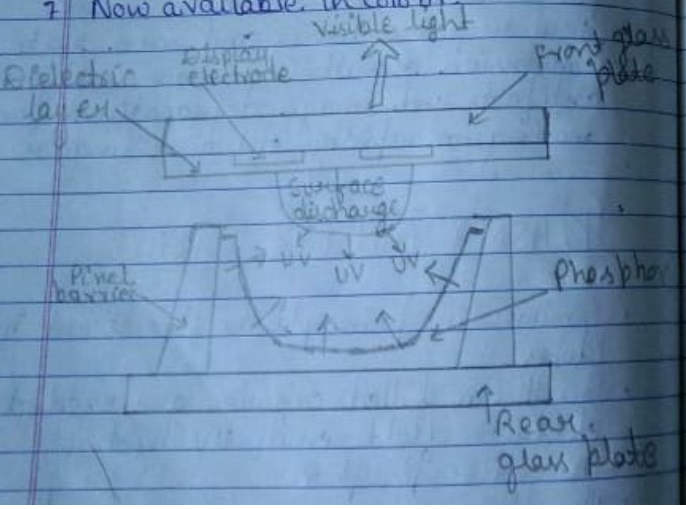
Vertical Video : cell phones is vertical video (9:16) that is planned for survey in picture mode. It was started by Snapchat and is additionally now being used by Twitter, TikTok, and Facebook.

→ a non-widescreen native aspect ratio.

Date.
Page No.

Structure of plasma panel display

1. Two glass plates seperated by neon gas
2. Vertical and horizontal conductors
3. Very rugged
4. No refreshing
5. Screens can be transparent and overlay documents
6. Used to be available in monochrome
7. Now available in colour.



Date.
Page No.

Advantages

a) Large viewing angle.
b) Good for large format displays
c) Better color accuracy and saturation.
d) Better motion tracking (little or no motion lag in fast moving images).

Disadvantages

- Expensive
- Phosphors gradually deplete.
- Large pixels (~ 1mm versus ~ 0.2 mm)
- Plasma Displays are more susceptible to "burn in" or "screen burn" of static image.
- Shorter display life span than LCD.
- Requires more power.

Date.
Page No.

- LCD is composed of several layers which include two polarized panel filters and electrodes. It is used for displaying the image in notebook or some other electronic devices like mini computers. Light is projected from a lens on a layer of liquid crystal. This combination of colored light with the grayscale image of the crystal (formed as electric current flows through the crystal) forms the colored image. This image is then displayed on the screen.

Advantages

- Produces very bright images due to high peak intensity. Very suitable for environments that are brightly lit.
- Produce considerably lower electric magnetic and electromagnetic fields than CRT.
- Consume less than 1/3rd the power of a comparable CRT.

Date.
Page No.

- Life span: 50,000 - 100,000 hours
- Screen size: 13 - 57 inches
- Power Consumption: (less power)
- Viewing Angle: Up to 165°, Picture suffers from the side.

Disadvantages:-

- The aspect ratio & resolution are fixed
- Lower contrast than CRTs due to a poor black-level
- Slow response times and scan rate conversion result in severe motion artifacts and image degradation for moving or rapidly changing images.

PLASMA PANEL DISPLAYS

- Similar in principle to fluorescent light tubes.
- Small gas filled capsules are excited by electric field emits UV light.
- UV excites phosphor
- Phosphor relaxes, emits some other color.

• LED delivers good picture quality.	LCD also delivers the good picture quality but less than LED.
• LED is costlier	It is less costlier
• LED have better black level and contrast in comparison to LCD	While it have not good black level & contrast as a LED.
• LED delivers better color accuracy	It also delivers good color accuracy.
• Have wider viewing angle than the LCD	While in LCD, the wide angle decreases with 30 degrees from the center in the image then the contrast ratio

FLAT PANEL DISPLAYS

↳ Volume (less space) → thinner than CRT
↳ Weight (light)
↳ Power (consumes less power)

Types

↓ Emissive Display

↓ Non Emissive Display

↓ Emissive Display (convert electric energy into light)
→ Plasma Panels
→ Thin film electroluminescent displays
→ LED

↓ Non Emissive Display (use optical effects to convert natural light)
↳ LCD

LCD (Liquid Crystal Display)

Light Wave ?
Scattered form means all dir^n.
↳ Electric Component
↳ Magnetic Component

Polarization of light ?
Movement of light component in one dir^n

Main three display components ?
↳ Light ↳ Color Filters ↳ Control Light

• It uses a liquid crystal to produce a visible image.

Date
Page No.

Disadvantages:-

a) The CRT's Gaussian beam profile produces images with softer edges that are not as sharp as an LCD at its native resolution. Imperfect focus and color registration also reduce sharpness, generally sharper than LCDs at other than native resolutions.

b) All color CRT produce annoying moiré patterns. Many monitors include Moiré reduction, which normally doesn't eliminate the moiré interference patterns entirely.

c) Subject to geometric distortion and screen regulation problems. Also affected by magnetic fields from other equipment including other CRTs.

d) Relatively bright but not as bright as LCDs. Not suitable for very brightly lit environments.

Date
Page No.

e) Some CRTs have a rounded spherical or cylindrical shape screen. Newer CRTs are flat.

f) CRTs give off electric, magnetic and electromagnetic fields. There is considerable controversy as to wheather any of these pose a health hazard, particularly magnetic fields. The most authoritative scientific studies conclude that they are not harmful but some people remain unconvinced.

g) They are large, heavy and bulky. They consume a lot of electricity and produce a lot of heat.

LED	LCD
• Light Emitting Diode	Liquid Crystal Display
• LED have better response time than LCD.	LCD is slower than LED in terms of response time.
• LED consumes more power in comparison to LCD.	It consumes less power.

Thus the de-excitation results in a bright-colored spot on the screen. The frequency (color) of the spot depends on the difference b/w the two energy levels (excited and ground-state level).

Different kinds of phosphors are used in a CRT. The difference is based upon the time for how long the phosphor continues to emit light after the CRT beam has been removed.
This property is referred to as Persistence.

Persistence means how much time is taken by the emitted light to reduce to one-tenth of its original intensity.
Now, phosphors with lower persistence require higher refresh rates to maintain a picture on the screen without any flicker.

Advantages of CRT

a) They operate at any resolution, geometry and aspect ratio without the need for rescaling the image.

b) CRTs run at the highest pixel resolutions generally available.

c) Produce a very dark black and the highest contrast levels normally available. Suitable for use even in dimly lit or dark environments.

d) CRTs produce the very best color and gray-scale and are the reference standard for all professional calibrations.
They have a perfectly smooth gray-scale with an infinite number of intensity levels. Other display technologies are Gamma curve of a CRT, but can only do so approximately.

e) CRTs have fast response times and no motion artifacts. Best for rapidly moving or changing images.

f) CRTs are less expensive than comparable displays using other display technologies.

Date
Page No.

Types of Deflection

1) Electrostatic Deflection

The electron beam (cathode rays) passes through a highly positively charged metal cylinder that forms an electrostatic lens.
This electrostatic lens focuses the beam of light. Two pairs of parallel plates are mounted inside the CRT tube. Electrostatic deflection sensitivity of a Cathode Ray Tube is the amount of deflection produced in the electron beam when a voltage of 1V is applied b/w the plates.

2) Magnetic Deflection

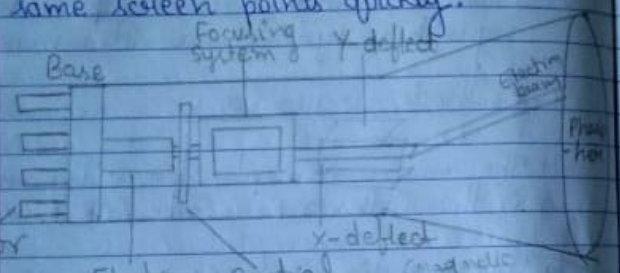
Here, two pairs of coils are used. One pair is mounted on the top and bottom of the CRT tube, and the other pair on the two opposite sides. The magnetic field produced by both these pairs is such that a force is generated on the electron beam in a dir which is ⊥ to both the direction of magnetic field and to the dir of flow of the beam. One pair is mounted horizontally and the other vertically.

Now as this highly energetic beam strikes the surface of the screen, these electrons are stopped and their kinetic energy is absorbed by the phosphor screen (atoms). Some energy is wasted in heat also, but the majority of the kinetic energy gets transferred to the phosphor atoms. As, these atom receive this huge amount of energy, they get excited to a higher energy level.

After a short time, these atoms start returning to their original energy level. The original level is at a lower energy level than excited one, hence the atoms release some energy while coming down. This extra energy is dissipated in the form of a small quantum of light.

Date.
Page No.

4. It redraws the picture by directing the electron beam back over the same screen points quickly.



Construction of a CRT

1. The primary components are the heated metal cathode and a control grid.

2. The heat is supplied to the cathode by passing current through the filament. This way the electrons get heated up and start getting ejected out of the cathode filament.

Date.
Page No.

3. This stream of negatively charged electrons is accelerated towards the phosphor screen by supplying a high +ve voltage.

4. This acceleration is generally produced by means of an accelerating anode.

5. Next component is the Focusing System, which is used to force the electron beam to converge to small spot on the screen.

6. If there will not be any focusing system, the electrons will be scattered because of their own repulsions and hence we won't get a sharp image of the object.

7. This focusing can be either by means of electrostatic fields or magnetic fields.

Pixels? (RGB)
Pix = Picture
Els = Elements
Picture + Elements = Pixels

Date
Page No.

- Display screen contains picture elements or pixels.
- Arranged in the form of a grid.
- When these pixels are excited by electrical means they emit light with specific intensities, which give us the sensation of the colored image on the screen.
- The mechanism for exciting pixels is the responsibility of the video controller
- Takes as input digital image stored in video memory and and activates suitable electro-mechanical mechanism for pixels to emit light.

Date
Page No.

Display Devices → (output devices)

Most commonly used output device in a graphics system is a video monitor.

Cathode-ray-tubes

- The main element of a video monitor is the Cathode Ray Tube (CRT).
- The operations of CRT is very simple:

1. The electron gun emits a beam of electrons (cathode rays).
2. The electron beam passes through focusing and deflection systems that direct it towards specified positions on the phosphor-coated screen.
3. When the beam hits the screen, the phosphor emits a small spot of light at each position contacted by the electron beam.

Date
Page No.

↳ Image generation is multi-stage process, involving lots of computation.

Idea:-
If all these computations are to be carried out by the CPU, it may get very less time for doing other computation tasks.
- System cannot do much except graphics

To avoid such situation and increase system efficiency, rendering is usually carried out by a dedicated component of the system (properly known as graphic card)

↳ Has its own processing unit (called GPU or graphics processing unit)

Video Memory

↳ CPU assigns any graphics rendering task to this separate graphics unit.

Date
Page No.

- We are calling it display controller as generic name.

Video Memory

↳ Display controller generates images in digital format strings of 0s & 1s

↳ The place where it is stored is video memory.
→ A (dedicated) part of the memory hierarchy of the system.
→ Typically part of the separate graphics unit (the VRAM in the graphic card).

Video Controllers

- It converts digital images to analog voltages.
↳ It takes stored images as input
↳ The analog voltages drive electro-mechanical arrangements, which ultimately render image on the screen.

Date
Page No.

↳ Trim (1980 Entertainment)

- Education And Training - It can be used to generate models of physical, financial and economic systems. These models can be used as educational aids.

- Image Processing : It is used to process image by changing property of the image.

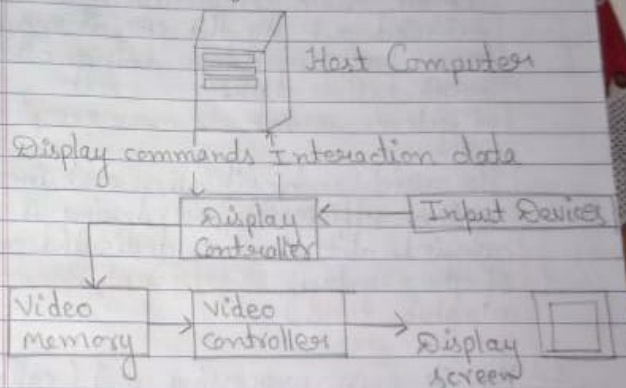
Why study Computer Graphics?

↳ Visualization
↳ Graphics is interesting ?
Involves simulation, algorithm, architecture
↳ Requirement ?
Just ask Intel
↳ Entertainment ?
Roll the video.

Date
Page No.

- What we do in CG - generate 2D images and display on the screen.

Generic CG System Architecture



Display Controller

Image generation task performed by display controller

→ Takes input from CPU (host computer)
→ As well as external input devices (mouse, keyboard, etc)

Date.
Page No.

- It provides facility called update dynamics. With this we can change the shape color and other properties of object.
- Now in recent development of digital signal processing and audio synthesis chip the interactive graphics can now provide audio feedback along with the graphical feed backs.

✱ Application of Computer graphics

- User interface: Visual object which we observe on screen which communicates with user. Ex: 3D Studio MAX
- Plotting of graphics and chart in industry, business, government and educational organizations drawing like bars, pie-charts, histogram's are very useful for quick and good decision making.

Date.
Page No.

- Computer aided drafting and design:- It uses graphics to design components and system such as automobile bodies structure of building etc.
- Simulation and Animation: Use of graphics in simulation makes mathematical models and mechanical systems more realistic and easy to study.
- Art & Commerce: There are many tools provided by graphics which allows used to make their picture animated and attracted which are used in advertising.
- Process Control: Now a day's automation is used which is graphically displayed on the screen.
- Cartography: is also used to represent geographic maps, weather maps, oceanographic charts, etc.
- Medicine & Virtual Surgery