Computer Graphics

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Computer graphics is one of the most effective and commonly used way to communicate the processed information to the user. It displays the information in the form of graphics objects such as pictures, charts, graphs and diagrams instead of simple text. ∴ we can say that computer graphics makes it possible to express data in pictorial form. The picture or graphics objects may be an engineering drawing, business graphs, architectural structures, a single frame from an animated movie or a machine parts illustrated for a service manual.

Advantages

Ability to store complex drawings and display them whenever needed.

Ability to visualize complex data in a simple and easy to understand manner. You can use graphs, pie charts etc to break down data and present it in a way that is easy to understand especially when you are communicating information to a non-technical audience.

Ability to design various logos, posters and other promotional materials using computer graphics software without hiring a designer ∴ it is a cost effective design solution.

Ability to create a high quality visual experience for users.

Computer graphics are available to everyone, regardless of location or ability.

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Disadvantages

Complexity : with the ↑ing demand for advanced tools applications are becoming complex for beginner users have to participate in graphical application training
For eg AutoCAD

Expensive : user need to participate in training sessions ∴ ↑es the cost on the other hand tools are very expensive for an individual user.

Time : It takes a lot of time and effort to create computer graphics

It is not easy to create effective computer graphics

Graphics is the processing and memory unit of computer which consumes high energy and makes the computer costlier.

Applications

Architectural Design : It involves the creation of 3D representations of buildings, landscapes, or other architectural designs. It shows how the design will look in real life

Education : 3D models of complex objects can be created thus enabling educators to create more interactive sessions and engage students
CG have changed the way to teach and learn

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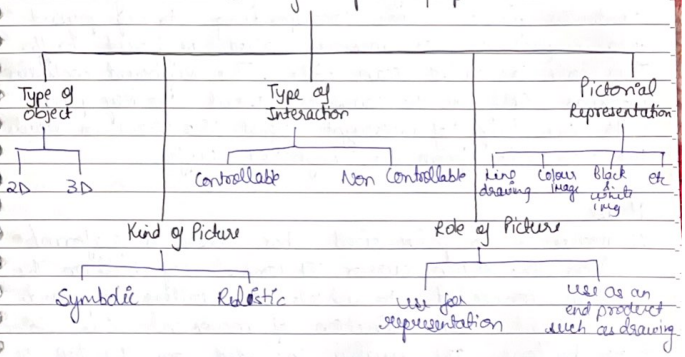
Scientific Visualization : CG have made it possible to gain insights into molecules structure.

Entertainment : CG are now commonly used in making motion pictures, music videos and television shows

Video Games : Many video games use 3D models to create a more realistic environment for players Most of the popular games have been created using computer graphics.

Cartography : CG is used to represent geo maps, weather maps, oceanographic charts etc



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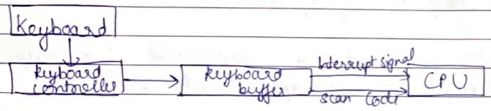
Graphics Hardware

It is a computer hardware that generates computer graphics and allows them to be shown on a display.

Input devices

1. Keyboard

It is used to enter text and numbers i.e on graphics data that is associated with pictures such as labels x-y coordinates etc



When we press a key on the keyboard, Keyboard controller places a code corresponding to key pressed into a part of its memory, called keyboard buffer. This code is called scan code. The keyboard controller informs CPU of the computer about the key press with the help of interrupt signal. The CPU then reads the scan code from the keyboard buffer.

2. Mouse

A mouse is a palm-sized box used to perform/position the screen cursor. It consists of ball on the bottom connected to wheels or rollers to provide the amount and direction of movement. One, two or three buttons are usually included on the top of the mouse for signaling the execution of some operation. Nowadays mouse consists of two buttons with one or more wheel on the top to scroll the screen pages.

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3. Trackball and Spaceball

Trackball is a 2-D positioning device, it is a ball that can be rotated with the fingers or palm of the hand to produce screen cursor movement. The potentiometer attached to the trackball are used to measure the amount and direction of rotation.

Spaceball provides 6 degree of freedom. It does not actually move. It consists of strain gauges which measure the amount of pressure applied to the spaceball. It is usually 3-D positioning and selecting operations in virtual-reality systems.

4. Joysticks

A joystick has a small, vertical lever (called the stick) mounted on the base and used to steer the screen cursor around. It consists of two potentiometers. The left or right movement is indicated by one potentiometer and forward or back movement is indicated by other potentiometer.

Output devices

- → Cathode Ray Tube
- → Vector scan display
- → Raster scan display
- → Coloured monitor
- → LCD, LED, TFT

Graphics Software

- → Photoshop
- → Maya 3D
- → CAD SIF
- → Corel Draw

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Display Devices

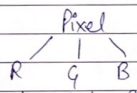
- → Pixel
- → Image resolution - PPI (Pixel density)
- → Aspect Ratio
- → CRT
- → Vector scan display
- → Raster scan display
- → Diff b/w Vector and Raster
- → Colour generation technique in Colour CRT
  - |→ Beam Penetration technique
  - |→ Shadow Mask technique

PIXEL (Picture element)

Pixel is the smallest addressable screen element. It is the smallest piece of the display screen which we can control. The control is achieved by setting the intensity and colour of the pixel which compose the screen.

In digital imaging, it is the smallest item of information in an image, arranged in 2-D grid (Rows & Cols) and are often represented as dots, squares, rectangles

Pixel is the smallest unit of display or video monitor. Intensity of each pixel is variable



8 bits (1 byte) 8 bits (1 byte) 8 bits (1 byte) = 24 bits = 3 bytes in 1 pixel

$2^8 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 256$ numeric values

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Total shades = $256 \times 256 \times 256 = 16.7$ millions shades
Composite of 3 RGB value creates final colour for one that pixel area

Image size = $1000 \times 750 = 750000$ pixels
$750000 \times 3 = 2250000$ bytes

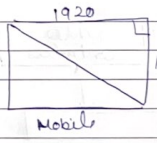
Resolution

The quality of the images printed or shown on a monitor is referred to as resolution. The resolution of a display is determined by counting the horizontal and vertical pixels. DPI is a resolution measurement used by printers (dots per inch)

PPI (Pixel per inch)

It refers to the number of pixels contained within each inch of a digital image.
higher the PPI, the better the image quality
Lower resolution images contain large pixels in fewer no.

Image Resolution
1920 × 1080
w × H



If
↑ resolution → w & H of image ↓
↓ resolute → w & H of image ↑

$(1920)^2 + (1080)^2 = x^2$

$x = \frac{2205}{5} = 440$ PPI

Aspect Ratio

It is the ratio of width to height of device
Eg aspect ratio of 3:1 means width of the graphic is three times of the height of the image.

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Frame Buffer

Frame buffer is a part of RAM in a computer allocated to hold the graphics data of one frame of image

Frame buffer size determines the maximum ~~depth~~ resolution and color depth of the image

FB size = resolution X color depth

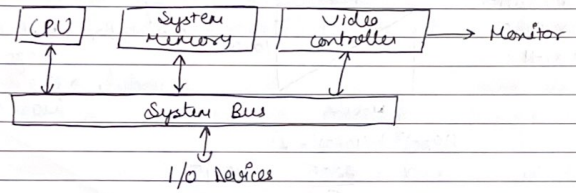
eg 640X480X 8 bit = 2457600 bit

= 307200 byte

Frame buffer can be a part of main memory, or on the video card

Image is generated by CPU / GPU and write (or load) into frame buffer.

Image in frame buffer is read out by video controller to display on the screen



Display Devices

Cathode Ray Tubes (CRTs)

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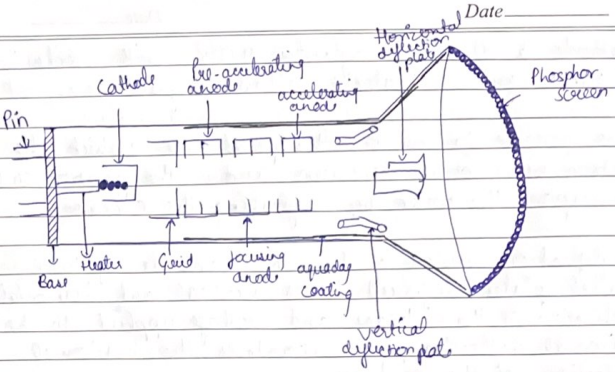

CRT stands for cathode ray tube. CRT technology is used in traditional computer monitors and televisions. The image on CRT display is created by firing electrons from the back of the tube of phosphors located towards the front of the screen.

→ CRT is a device which convert electrical signal (voltage, current) into visual signal

→ Cathode emits e^- when its get heat up by heater

→ Grid focuses & pass e^- beam at high speed.

→ Pre-accelerating anode → focusing anode → accelerating anode provide path

→ Vertical deflection plate deflects e^- beam in up & down direction on screen

→ Horizontal deflection plate deflects e^- beam in right & left direction

→ Aquadag coating → if e^- comes out of their path then it repels them and helps e^- to come to focusing path

→ Screen is coated with phosphor

→ Metal used in the screen is of zinc sulphate or zinc oxide or zinc tungston.

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→ Cathode is of nickle cylinder created with oxide
→ Electron gun → heater + cathode + grid

It is possible to control the point at which the electron beam strike the screen and ∴ the position of the dot upon the screen by deflecting the e⁻ beam

The deflection system of the CRT consists of two parallel plates, referred to as vertical and horizontal deflection of the e⁻ beam and voltage applied to the horizontal deflection plates controls the horizontal deflection of the e⁻ beam.

Once the electron hits the phosphorus, they light up and they are projected on a screen. The color you view on the screen is produced by a blend of red, blue and green light.

There are two techniques used for producing images on the CRT screen: Vector scan/random scan and Raster scan

Vector scan / Random scan display
Calligraphic display / stroke-writing display

Vector scan is a technique used for producing images on the screen.
Beam is directed to the area on the screen where the picture is to be drawn.

If we want a line connecting point A and point B on vector graphics display, we simply deviate the beam deflection circuitry, which will cause beam to go

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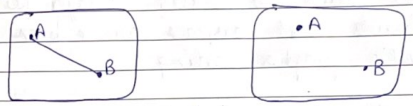
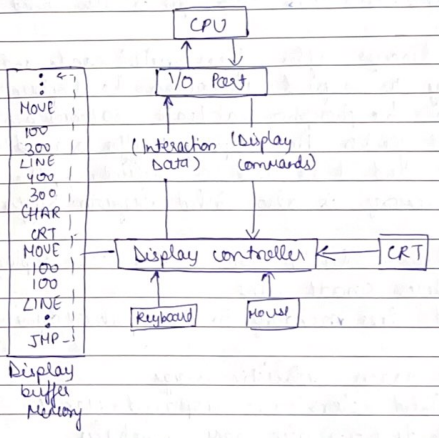
directly from point A to B. If we want to move the beam from point A to B without showing a line between points, we can blank the beam as we move it. To move the beam across the CRT, the information about both magnitude and direction is required. This info is generated with the help of vector graphic generator.



vector scan CRT



"Architecture of a vector display"

This architecture consist of display controller, CPU, display buffer memory and a CRT. A display controller is connected as an I/O peripheral to CPU. The display buffer memory stores the computer produced display list or display program. The program contains point

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and line plotting commands with (x, y) or (x, y, z) end point coordinates, as well as character plotting commands. The display controller interprets commands for plotting points, lines and characters & sends digital end point coordinates to a vector graphics generator. The vector generator then converts the digital coordinate values to analog voltages for beam-deflection circuits that displace an e-beam creating on the CRT's phosphor coating.

In vector display the beam is deflected from end point to end point, hence this technique is also called random scan.
Phosphor light decays after few milliseconds and ∴ it is necessary to repeat through the display list to refresh the phosphor at least 30 times per second to avoid flicker. As display buffer is used to store display list and it is used for refreshing, the display buffers memory is also called refresh buffer.

Advantages :- • higher resolution than raster scan display
• produce smooth line
• need less memory to store picture definition

Disadvantages :- • can't draw realistic image
• Limited colors to be displayed - Max 4 depends how deep beam penetrates.

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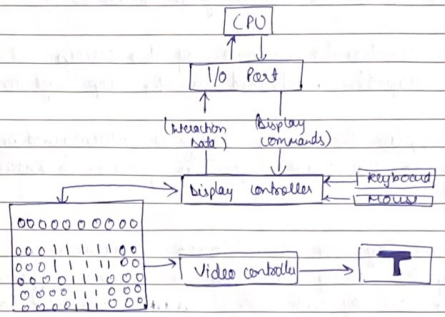
Raster scan display



Refresh Buffer

The display image is stored in the form of 1s and 0s in the refresh buffer. The video controller reads the refresh buffer and produces the actual image on the screen. It does this by scanning one line at a time, from top to bottom and then back to top

Raster scan CRT

It is the most common method of displaying image on the CRT screen.
In this horizontal and vertical deflection signals are generated to move the beam all over the screen.
The beam is swept back and forth from the left to

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right, it is ON when the beam is moved from L to R it is OFF when beam is moved from R to L

When the beam reaches the bottom of the screen, it is made OFF and rapidly retraced to the top left to start again.
In raster scan display, the screen image is maintained by repeatedly scanning the same image. This process is known as refreshing of screen.

In raster scan display a special area of memory is dedicated to graphics only known as frame buffer which holds the set of intensity values for all the screen points.
Each screen point is referred to as pixel which is specified by its row and col no.

Random Scan	Raster Scan
1. It has high resolution	It has low resolution
2. It is more expensive	It is less expensive
3. Modification is easy	Modification is tough
4. Solid pattern is tough to fill	Solid pattern is easy to fill
5. Refresh rate depends on resolution	Refresh rate does not depend on the picture
6. Only screen with view on an area is displayed	whole screen is scanned
7. Beam penetration technology come under it	Shadow mask technology come under this
8. It does not use interlacing method	It uses interlacing
9. It is restricted to line drawing applications	It is suitable for realistic display

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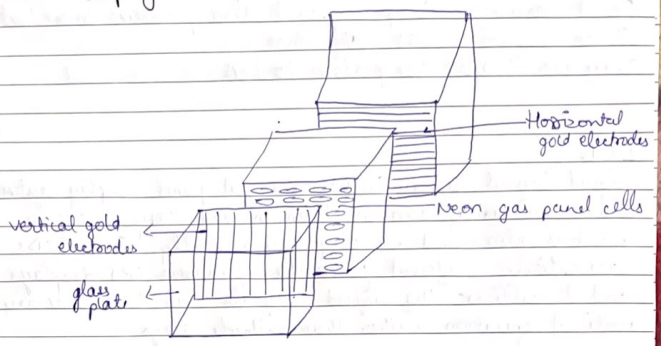
Plasma Display



Plasma display is composed of two parallel sheets of glass that enclose a mixture of discharge gases composed of helium, neon and xenon.

On the inner side of the glass plates are Ribs, which help keep the glass plates parallel

As another name of the plasma panel is gas discharge display, because of the gases filled in b/w the parallel plates. Plasma panel is available in both the colors black & white and also color type

Plasma displays are thinner than cathode ray tube and brighter than LCDs. A plasma display panel is a type of flat panel display common to large TV displays 30 inches or larger.

It consumes more power.
They have poor performance at high altitudes due to the pressure in between the cases and also high air pressure at altitudes

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It has lower brightness, so it is viewed in darkened rooms
As it consumes more power, so it also produces more heat
Screen surface is less reflective
They are cheaper comparison to LCD

LCD

Liquid Crystal Display (LCD) is a flat panel display system that is primarily seen in television and computer screens, which is also used by cell phones presently. Such LCDs are entirely different from the previous CRT displays and it utilizes the liquid crystals as their primary mode of operation rather than cathode rays.

LCD consists of millions of pixels created from crystals and organized in a rectangular pattern on the LCD panel. LCD has backlights that bring light to every pixel. Every pixel has a sub-pixel (RGB), red, green & blue which can be switched off or on. When all subpixels are switched off, it is black, while all subpixels are switched on a hundred per cent, then it is white.

LCD is used in various device like mobile device, laptops, computers, digital clocks, gaming systems etc

LCD has low cost, energy efficiency & less toxic energy consumption
LCD is smaller and thinner and is very flexible
LCD screen radiation is slightly lesser than the CRT monitors

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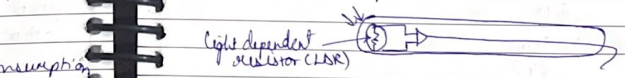
LED	LCD
• LED has a better response time than LCD	LCD is slower than LED in terms of response time
• LED consumes more power in comparision to LCD	LED consumes less power in comparison to LED
• LED is costlier	LCD is less costly
• It delivers good picture quality than LCD	It also delivers good picture but less than LED
• It has better black level and contrast	It has not good black level and contrast
• deliver better color accuracy	it also deliver better color accuracy but there is a difference between LED and LCD
	LCD uses liquid crystals and glass electrodes
• LED uses gallium arsenide phosphide	it requires mercury
• no mercury is used	range 13 - 57 inches
• Range upto 90 inches	wide-angle res with 30°
• It has wider view angle	

Light pens

Light pen is a pencil shaped device used to select positions by detecting the light coming from points on the CRT screen. It consists of a photoelectric cell housed in a pencil like case



A light pen is a light sensitive computer input device, basically a stylus, that is used to select text, draw pictures and interact with user interface elements on a computer screen or monitor. The light pen works well with CRT monitors

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Q How many K bytes does a frame buffer need is a 600 X 400 pixel?

Ans Resolution = 600x400

size of frame buffer = Resolution x bits per pixel

= 600x400 x n

= 240000n bits

wkt 1 Kb = 1024 byte

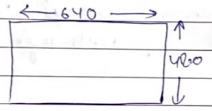
1 byte = 8 bit

$= \frac{240000 \times n}{1024 \times 8}$

$= 29.30n$ Kb

Q Compute the size of 640 X 480 image at 240 pixels per inch

Ans



240 pixels = 1 inch

1 pixel = $\frac{1}{240}$ inches

$W = \frac{640}{240}$ $H = \frac{480}{240}$

Total size = W x H

$= \frac{640}{240} \times \frac{480}{240}$

$= 5.33$ inch^2

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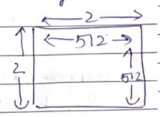
Q Compute the resolution of 2x2 inch image that has 512 x 512 pixel

Ans Resolution means no of pixels per unit length

$\frac{512}{2} \times \frac{512}{2} = 256 \times 256$



Q If an image has height of 2 inch and aspect ratio is 1.5 calculate its width

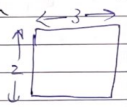
Ans Aspect ration = $\frac{W}{H} = 1.5$

$\frac{W}{2} = 1.5$

W = 3 inch

Q Calculate total no of pixels for a 3x2 inch image at a resolution of 300 pixels per inch

Ans



1 inch = 300 pixels

2 inch = 600 pixels

3 inch = 900 pixels

Total no of pixels = 600 x 900 pixels

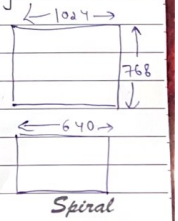
Q Resize a 1024 x 768 image to one that is 640 pixel wide with the same aspect ratio, find its height.

Ans Aspect ratio$_1$ = $\frac{1024}{768}$

Aspect ratio$_2$ = $\frac{640}{H}$

$\frac{640}{H} = \frac{1024}{768}$

H = 468



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Q Find out the aspect ratio of the raster system using 8X10 inches screen and 100 pixel/inch

Ans $AR = \frac{W}{H} = \frac{48 \times 100}{5 \times 10 \times 100} = 4:5$

Q Suppose RGB raster system is to be designed using 8 inch X10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 6 bits per pixel in the frame buffer, how much storage (in bytes) do we need for frame buffer?

Ans Resolution = 8X10
= 8X100 X10X100
= 800 X1000 pixel

1 pixel can store 6 bits

size of frame buffer = 800X1000 X6 bits
$= \frac{800 \times 1000 \times 6}{8}$ bytes
$= 6 \times 10^5$ bytes

Q How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution of 1280 X1024 and a refresh rate of 60 frames per second?

Ans Resolution = 1280X1024 pixel
refresh rate = 60 frame /sec
1 frame = $\frac{1}{60}$ sec

Time of scanning on row = $\frac{1 \times 1024}{60}$
$= 1.627 \times 10^{-5}$ sec

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Q Consider three different raster systems with resolutions of 640 X480, 1280 X1024 and 2560 X2048

a) what size is frame buffer (in bytes) for each of these systems to store 12 bits per pixels

frame buffer = $\frac{640 \times 480 \times 12}{8}$ = 450 bytes
$= \frac{1280 \times 1024 \times 12}{8}$ = 1920 bytes
$= \frac{2560 \times 2048 \times 12}{8}$ = 7680 bytes

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

frame buffer = $\frac{640 \times 480 \times 12 \times 2}{8}$ = 900 bytes
$= \frac{1280 \times 1024 \times 12 \times 2}{8}$ = 3840 bytes
$= \frac{2560 \times 2048 \times 12 \times 2}{8}$ = 15360 bytes

Q Consider two raster systems with the resolutions of 640X480 and 1280 X1024

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?

Ans Resolution = 640 X480
$= 640 \times 480 \times 60 = 1.8432 \times 10^7$ p/s
$= 1280 \times 1024 \times 60 = 7.86432 \times 10^7$ p/s

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

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access time per pixel = 1/access rate

$= \frac{1}{640 \times 480 \times 60}$ = 54 nanoseconds

$= \frac{1}{1280 \times 1024 \times 60}$ = 12.7 nanoseconds.

Q Consider a raster system with the resolution of 1024 × 768 pixels and the color palette calls for 65536 colors. What is the minimum amount of video RAM that the computer must have to support the above mentioned resolution and number of colors?

Ans
no of colors = 65536
no of bits per pixel = $\log_2(65536)$
= 16 bit color
Resolution = 1024 × 768
Total no of bits = 1024 × 768 × 16
= 1572864 bytes
= 1536 KB
= 1.5 MB

Q How long does it take to load a 640 × 480 frame buffer with 12 bits per pixel, if 10^5 bits can be transferred per second?

Ans
Resolution = 640 × 480
no of bits = 640 × 480 × 12
= 3686400 bits
1 sec = 10^5 bits
x sec = 3686400 bits
$x = \frac{3686400}{10^5}$ = 36.864 second

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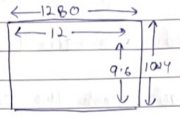
Q Suppose we have a video monitor with a display area with 12 inches width and 9.6 inches high. If the resolution is 1280 × 1024 and the aspect ratio is 1, what are the width and the height of each point on the screen?



$\frac{1280}{1024} = \frac{12}{9.6} = 1$

1 pixel width = $\frac{12}{1280}$ = 0.009375 inches

1 pixel height = $\frac{9.6}{1024}$ = 0.009375 inches

Q What do you mean by computer graphics?
The branch of science and technology concerned with methods and techniques for converting data to or from visual presentation using computers.
- Create an image
- Store the image in the memory
- Display the image on disply device
- Make a processing on the image
- Interact with the image

Q What are the applications of computer graphics?
- Computer Aided Design
- Graphical User Interface
- Entertainment
- Simulation and Training
- Education and Presentation
- Computer Generated Art
- Scientific Visualization
- Image Processing
- Virtual reality

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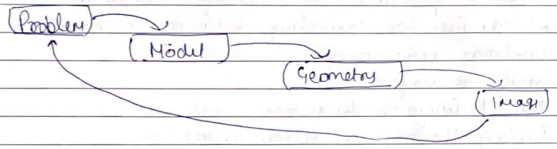
Q What can the programmer do in computer graphics?

- Develop the geometric representation for the geometric objects of the images
- Assemble these objects into an appropriate geometric space
- Define some animation for the image
- Specify how the scene is to be viewed and how it will be displayed on the graphic device
- Design a ways for the user to interact with the scene as it is presented

Q How can the computer graphics used in solving problems?

CG can solve a lot of problems

- Identifying a problem
- Building the model
- Represent the problem geometrially and create an image
- Use the image to understand the problem and try find a possible solution.



Q Computer Graphics API

Graphic API's is a set of tools that allows a programmer to create applications that include the use of interactive computer graphics without dealing with system details for tasks such as window handling and interactions.

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Q What do you mean by GUI?

GUI stands for Graphical user interface. A major component of a GUI is a window manager that allows a user to display multiple-window areas. To make a particular window active we simply click in that window using an interactive pointing device. Interfaces also display menus and icons for fast selection of processing options or parameter values.

Q What does it mean by RGB?

The RGB is a color model, in which red, green and blue light are added together in various ways to reproduce a different array of colors. The name of the model comes from the initials of the three additive primary colors red, green and blue

Q Define refresh buffer / Frame buffer

Picture definition is stored in a memory area called the refresh buffer or frame buffer. This memory area holds the set of intensity values for all the screen points

Q Define pixel

Each screen point is referred to as a pixel or pel (picture element)

Q Define bitmap

On a black and white system with one bit per pixel, the frame buffer to refresh the screen.

Q What is the role of a video controller?

It is used to control the operation of the display device by accessing the frame buffer to refresh the screen.

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Q Define Graphics controller/Display Controller / Display processor
The purpose of the display processor is to free the CPU from graphic chores. [A major task of the display processor is digitizing a pictured 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

Q Describe the basic components of computer graphics system?
A computer graphics system is a computer system that have all the components of a general-purpose computer system.
There are six major elements in our system
- Input devices
- Central Processing Unit
- Graphics Processing Unit
- Memory
- Frame Buffer
- Output devices

Q Define persistence in terms of CRT phosphorous
Persistence is the one of the major property of phosphorous used in CRTs. It means how long they continue to emit light after the electron beam is removed

Q Define resolution
The maximum no of points that can be displayed without overlap on a CRT monitor

Q What do you mean by an aspect ratio?
Aspect ratio is the ratio of vertical points to horizontal points necessary to produce equal length lines in both directions on the screen. An aspect ratio of 3/4 means that a

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vertical line plotted with three points has same length as a horizontal line plotted with 4 points

Q what are the different properties of phosphorous?
Color
Persistence

Q What are the different types of flat-screens and what is the difference between them?
light-emitting diodes (LEDs) – light-emitting diodes that can be turned on and off
Liquid-crystal displays (LCDs) – polarization of the liquid crystals in the middle panel
plasma panels – voltages on the grids to energize gases.

Similarities
- All uses a 2-D grid to address individual light-emitting elements
- The two outside plates each contain perpendicular parallel grids of wires
- Sending electrical signals to a wire in each grid, generates electrical field at the

Intersection of two wires, can control the corresponding element in the middle plate.

Q What do you mean by retracing? Define horizontal as well as vertical retracing.
Retracing → At the end of each scan line, the e-beam returns to the left side of the screen to begin displaying the next scan line.

Horizontal retrace → The return to the left of the screen, after refreshing each scan line

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Vertical retrace → At the end of each frame, the e⁻ beam returns to the top left corner of the screen to begin the next frame.

Q What is a Beam penetration method?
This technique is used in random scan display systems. Two layers of phosphor (red and green) are coated onto the inside of the CRT screen, the displayed colors depends on how far the e⁻ beam penetrates into the phosphors layer. A slow e⁻ beam excites only the outer red layer. A very fast e⁻ beam penetrates through the red layer and hence excites the green layer. An average e⁻ beam gives the combination of red and green color. That is yellow and orange. This technique only provides four colors.

Q Define shadow masking.
This technique is used in raster scan display devices. It gives more colors than a beam penetration method. A shadow mask CRT has three phosphor color dots at each pixel location (red light, green light and blue light). This type of CRT also has 3 e⁻ guns one for each color dot. A shadow mask grid is installed just behind the phosphor coated screen.
When the three beams pass through a hole in the shadow mask they activate a dot triangle which appears as small color spot on the screen.
More than 17 million different colors can be obtained in a full color system.

Q What are the popular image storage formats?
The popular image storage formats are

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Jpeg format
This lossy format compresses image blocks based on thresholds in the human visual system. This format works well for natural images.

Tiff format
This format is most commonly used to hold binary images or lossless compressed 8 or 16 bit RGB although many other options exist.

Ppm format
A lossless, uncompressed format is most often used for 8 bit RGB images although many options exist.

Png format
This is a set of lossless formats with a good set of open source management tools.

Q What do you mean by interlacing?
It is the method of incrementally displaying a visual on a CRT. On some raster scan systems, each frame is displayed in two passes using an interlaced refresh procedure. In the first pass, the beam steps across every other scan line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines.

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