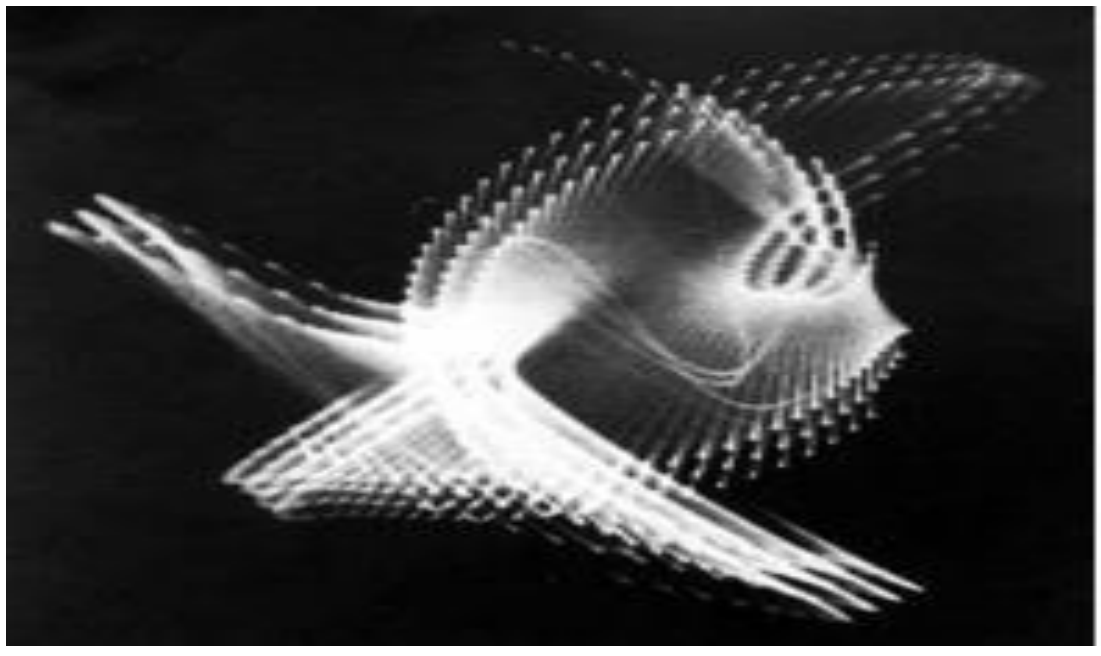
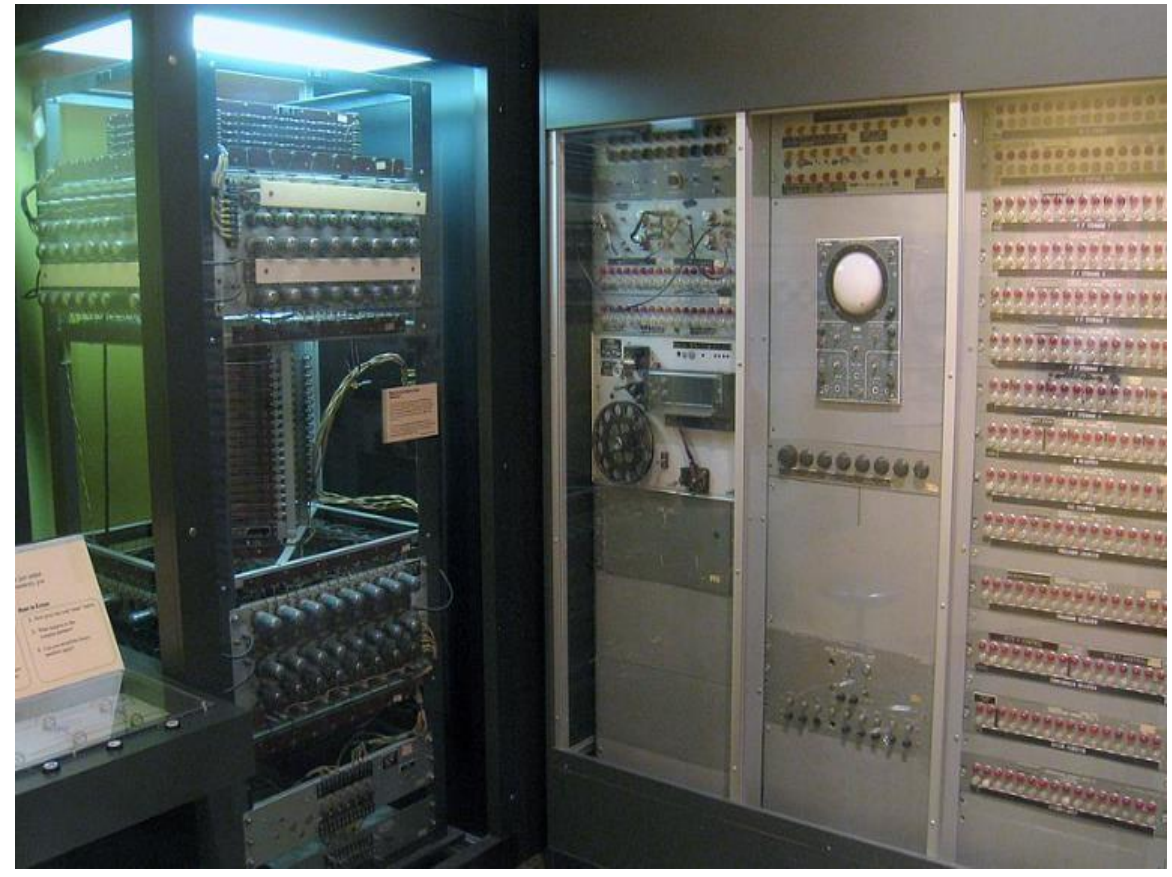
Introduction to Computer Graphics

- The term ‘Computer Graphics’ was coined by Verne Hudson and William Fetter from Boeing who were pioneers in the field.
- Computer graphics is a dynamic and essential field within computing that involves the creation, manipulation, and rendering of visual content using computers.
- Computer graphics is an art of drawing pictures using computers
- Computer graphics are graphics created using computers and the representation of image data by a computer specifically with help from specialized graphic hardware and software.
- It includes the creation, storage, and manipulation of images of objects .
- These objects come from diverse fields such as physical, mathematical, engineering, architectural

History of computer graphics

- **1950** : The first graphic images are created by Ben Laposky using an oscilloscope to generate waveform artwork produced by manipulating the analog electronic beams.



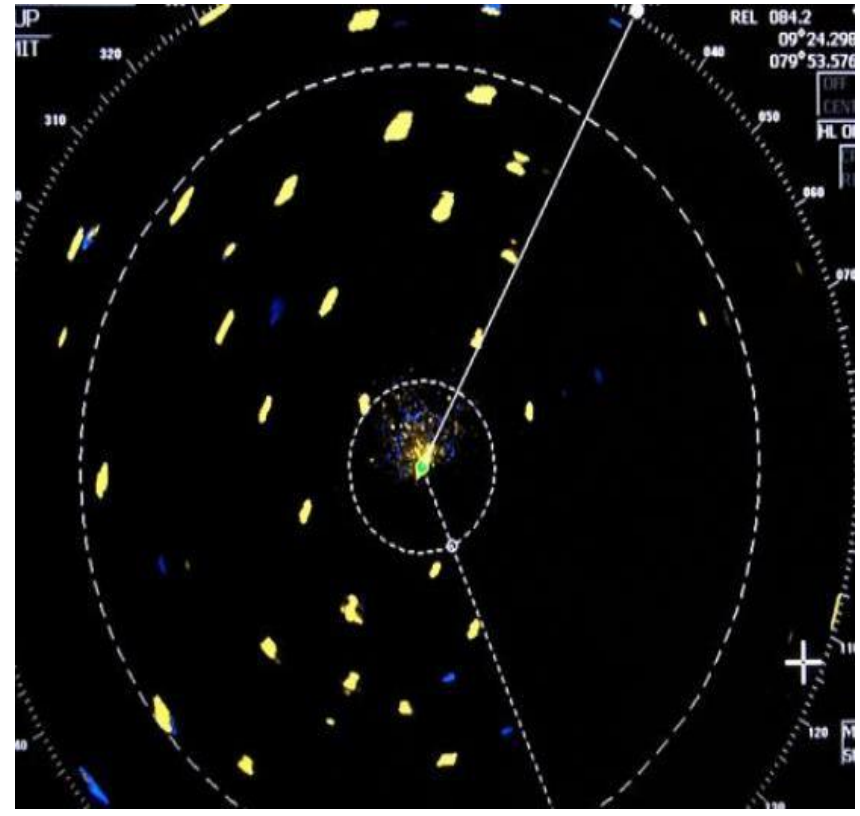


1951: Jay Forrester and Robert Everett of the Massachusetts Institute of Technology (MIT) produce the Whirlwind, a mainframe computer with a CRT to plot blips representing incoming aircrafts based on radar-gathered data

- Designed to support military preparedness

1955:

- Direct descendant of the Whirlwind, the SAGE (Semi Automatic Ground Equipment) air defense system is designed by Bert Sutherland at MIT.
- It uses simple graphics to display on analog CRTs radar images with a wireframe outline of the region being scanned
- As well as the first light pen as an input device that operators would use to pinpoint planes flying over regions of the United States.
- It becomes a key part of the US missile defense system.

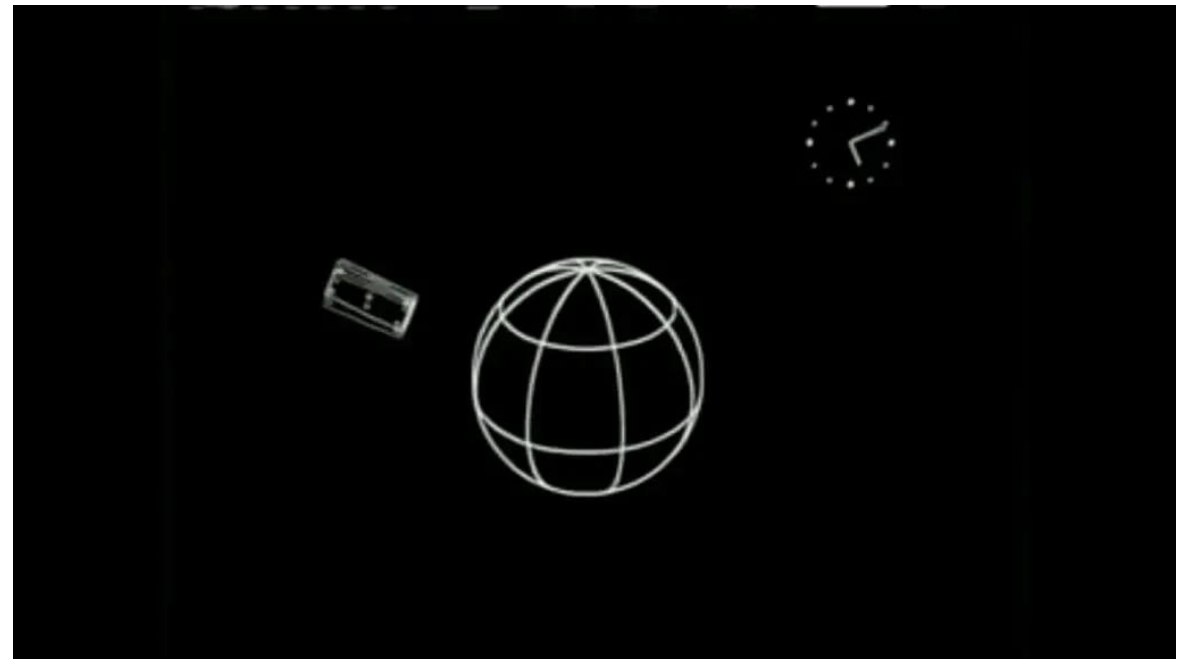


1959:

General Motors and IBM develop "DAC-1" (Design Augmented by Computers), the first industrial CAD system (Computer-Aided Design) used to help engineers design cars. It allows a user to rotate and view a simple drawings.

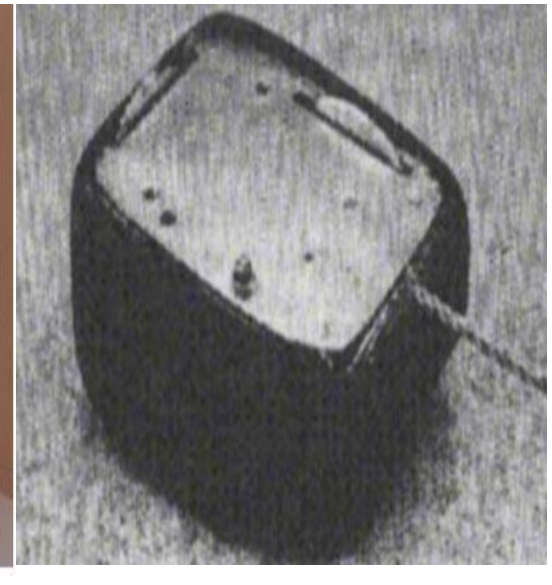
1960: The term ‘Computer Graphics’ was coined by William Fetter.

1963: E.E. Zajac of the Bell Telephone Laboratory created a film using animations and graphics which could show the movement of satellites and their change in altitudes around the orbit of the Earth.



1963:

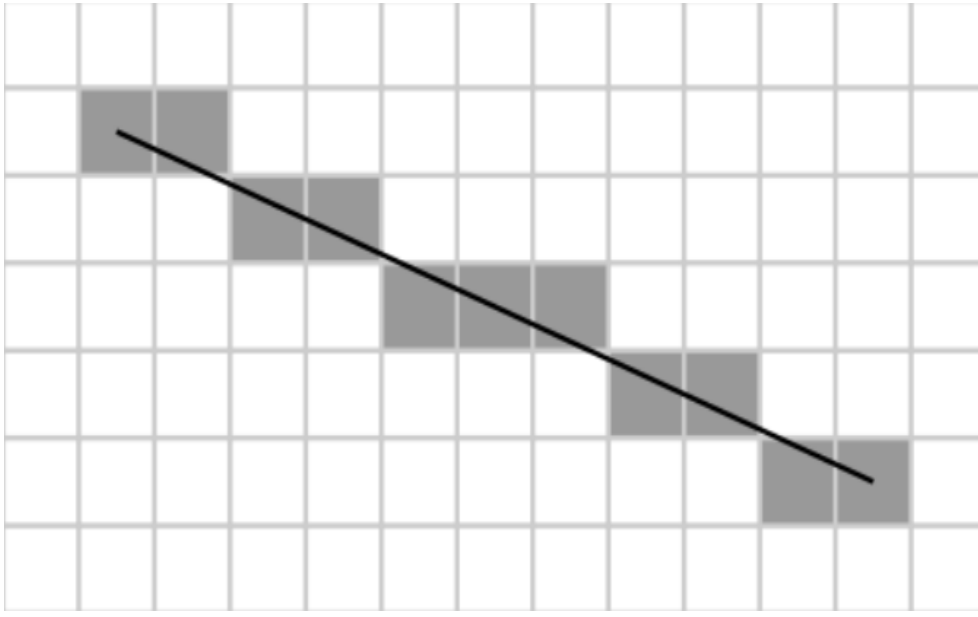
- For his doctoral thesis at MIT, Ivan Sutherland develops Sketchpad, the first Computer-Aided Drafting and Design (CADD) package.
- Allowing shapes to be interactively drawn on a display monitor using a light pen input device wired into the computer.
- The light pen uses a small photoelectric cell in its tip to emit an electronic pulse when the pen “sees” the electron beam.



1963:

- **Larry Roberts** develops the first effective hidden-line removal algorithm.
- The mouse is invented by **Doug Englebart** at the Stanford Research Institute (SRI).

1965: The digital line drawing algorithm for raster devices developed in 1962 by Jack Bresenham at IBM is published.



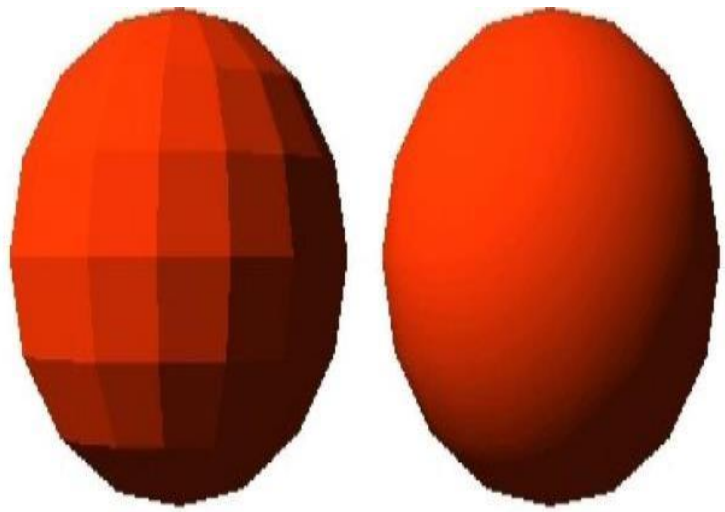
1968: Frustrated by the lack of graphics hardware available,
Evans & Sutherland then found their own company.

1968: Intel is founded.

1969: The first framebuffer (with 3 bits per pixel) is built at Bell Labs.

1969: The ACM initiated A Special Interest Group on Graphics (SIGGRAPH) which organizes conferences, graphics standards, and publications within the field of computer graphics.

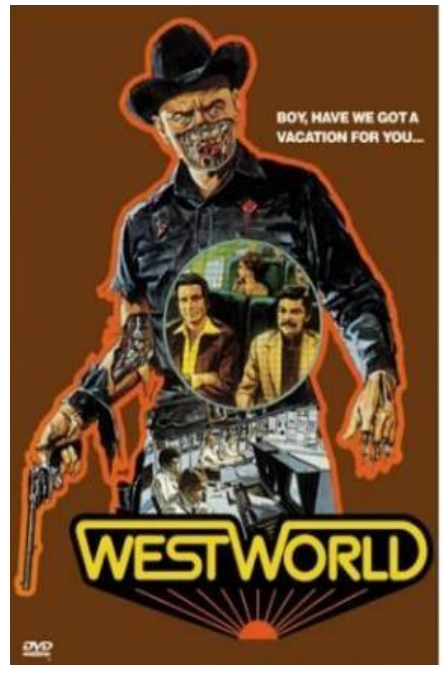
1971: Gouraud shading is developed by Utah student **Henri Gouraud**. By interpolating intensity, visual improvements over flat shading may be achieved at a marginal cost.

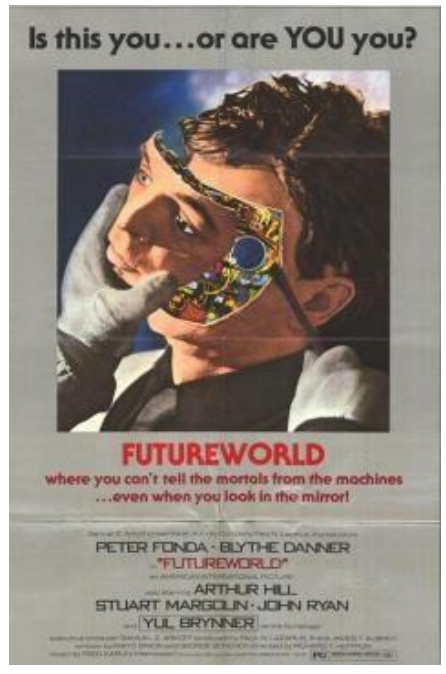


1972: Raster images started to appear, which is an image type that consists of pixels.

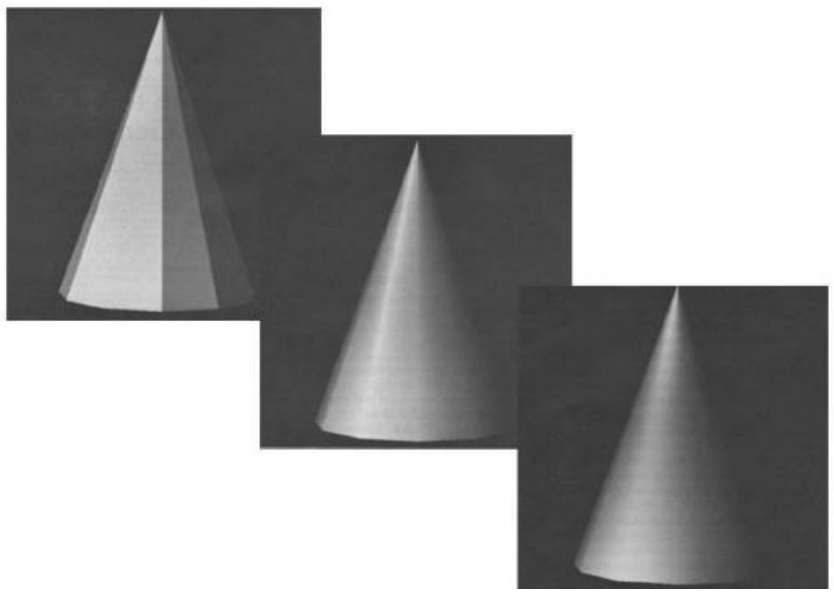
1973: The concept of Z-buffer algorithm and texture mapping were developed by **Edwin Catmull.**

- **1973:** The entertainment feature film Westworld makes the first use of 2D animation, while 3D wireframe CGI **(computer- generated imagery)** 3 years later in its sequel Futureworld.





1975: Utah student Bui Tuong Phong develops a specular illumination model. He also introduces the interpolation of normal for shading, now known as Phong shading.



1975:

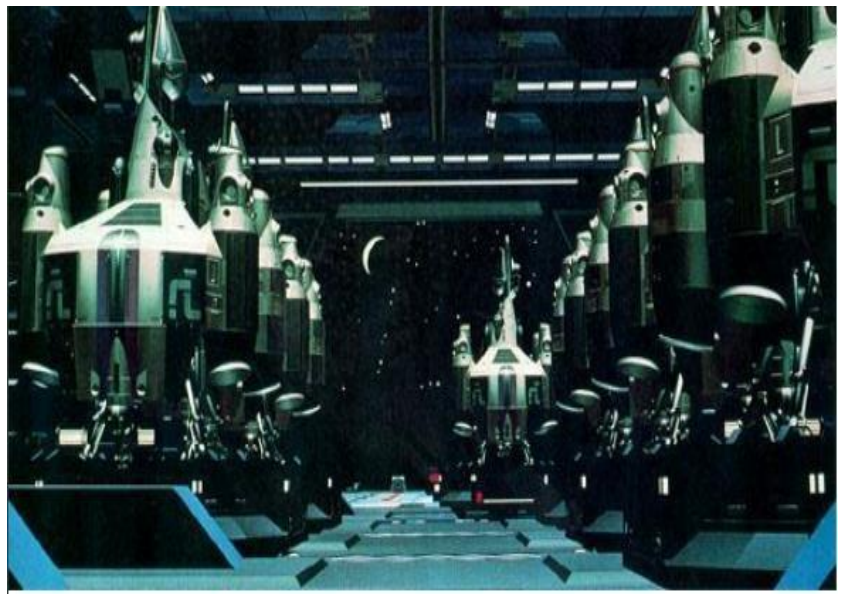
- Using Bezier patches, Utah student Martin Newell creates a 3D computer model of a physical teapot, now at the Computer Museum in Boston.
- Serving as a benchmark throughout history, the Utah teapot has become an icon of 3D computer graphics.
- At the age of **19**, **William (Bill) Gates III** dropped out of Harvard and founds Microsoft with his friend **Paul Allen.**

1980: The European Association for Computer Graphics is formed and the first EUROGRAPHICS conference held in Geneva.

1982:

Japan's Osaka University developed a supercomputer that used 257 Zilog Z8001 microprocessors to display realistic 3D graphics.

The first broad use of 3D graphics animation was done in a Disney featured film.



1984:

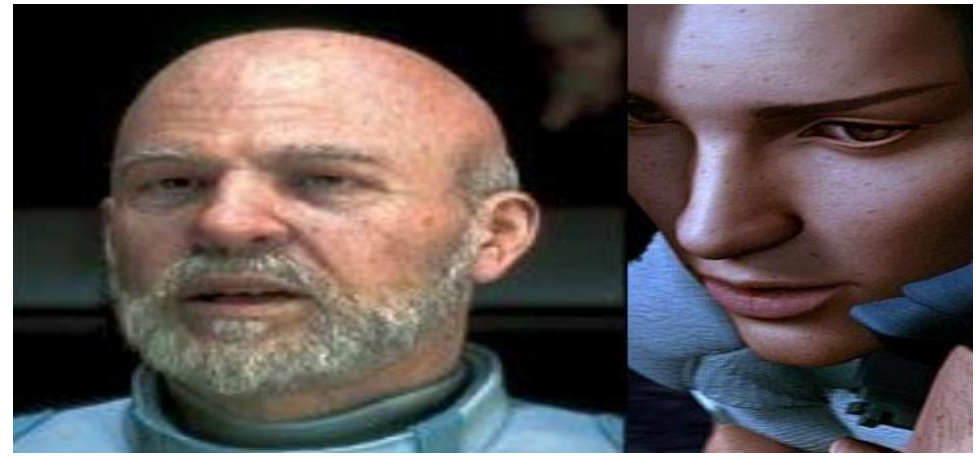
- The first movie to use "integrated CGI" where the effects are supposed to represent real world objects is released.
- The Last Starfighter includes CG spaceships, planets, and high-tech hardware integrated into live-action scenes

1993: Nvidia is founded, later attracts many engineers from SGI and other companies to become the main graphics HW company (besides ATI and Intel today).
SGI: Silicon Graphics Inc.

1995: Pixar Animation Studios produce Toy Story, the first computer-animated full-length feature film, demonstrating the possibilities of CGI graphics in moviemaking.

2000: The first web-based CAD system Sketchup released.

2001: Although it fails commercially, Final Fantasy - The Spirits Within is the first feature-length digital film that includes a cast of photorealistic digital actors



2004:

Facebook was created by Mark Zuckerberg in a college dorm at Harvard. Facebook has enhanced our lives because it quickly became one of the most used social medias.

2005:

YouTube was launched by Steve Chen, Chad Hurley, and Jawed Karim.

2006:

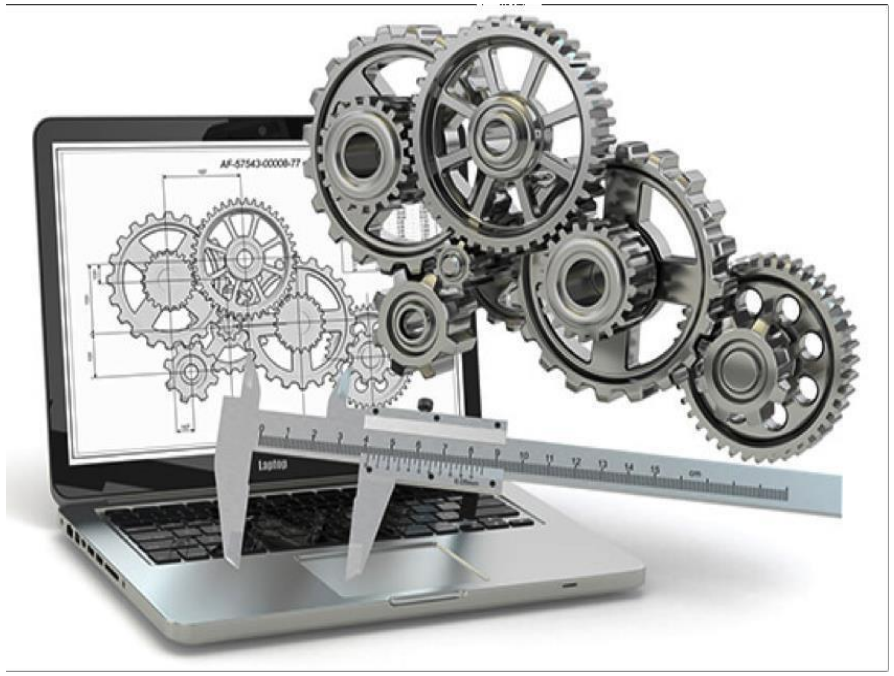
Google acquires Sketchup.

2. Application Of Computer Graphics

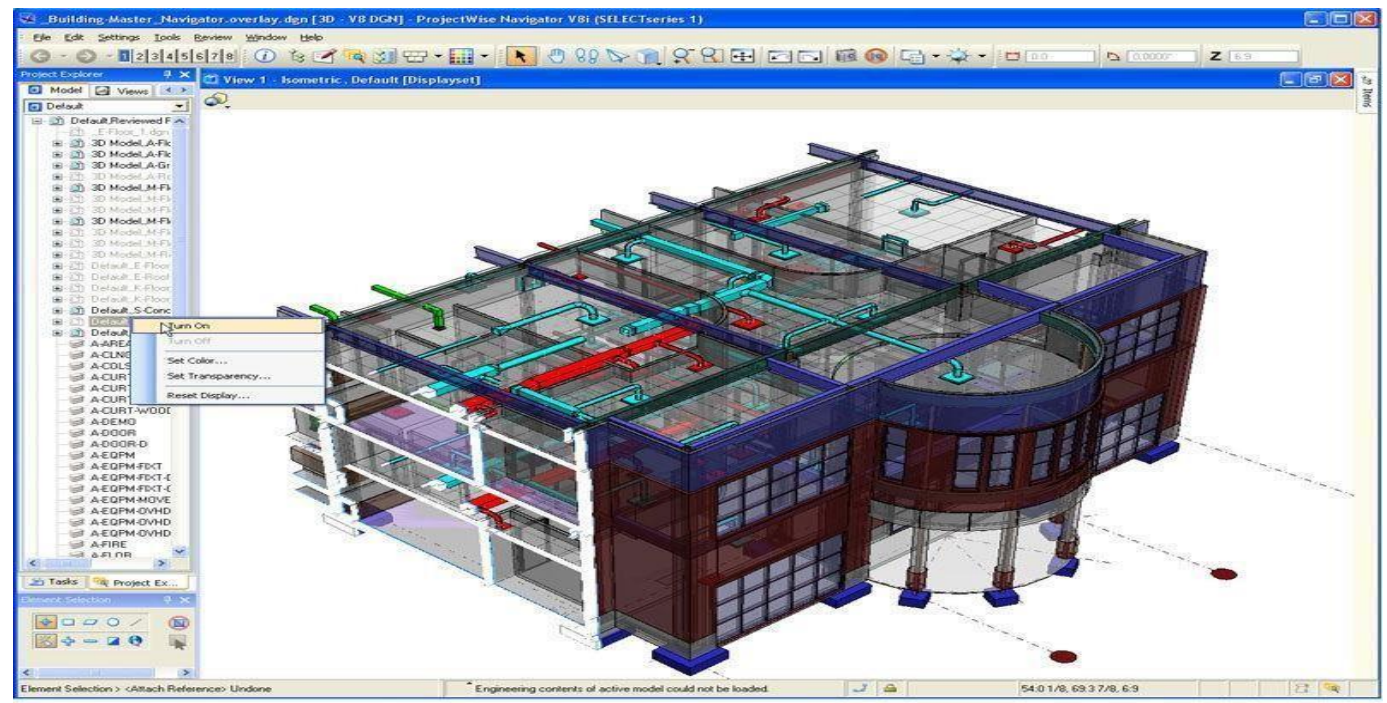
- Computer Aided Design (CAD)
- Presentation Graphics
- Computer Art
- Entertainment
- Education and Training
- Visualization
- Graphical User Interfaces (GUI)
- Simulation
- Cartography

Computer Aided Design (CAD)

- In CAD, graphics is used to design components and systems of mechanical, electrical, electro-mechanical and electronic devices including structures such as buildings, automobile bodies, airplane, VLSI chips, optical systems and telephone and computer networks.



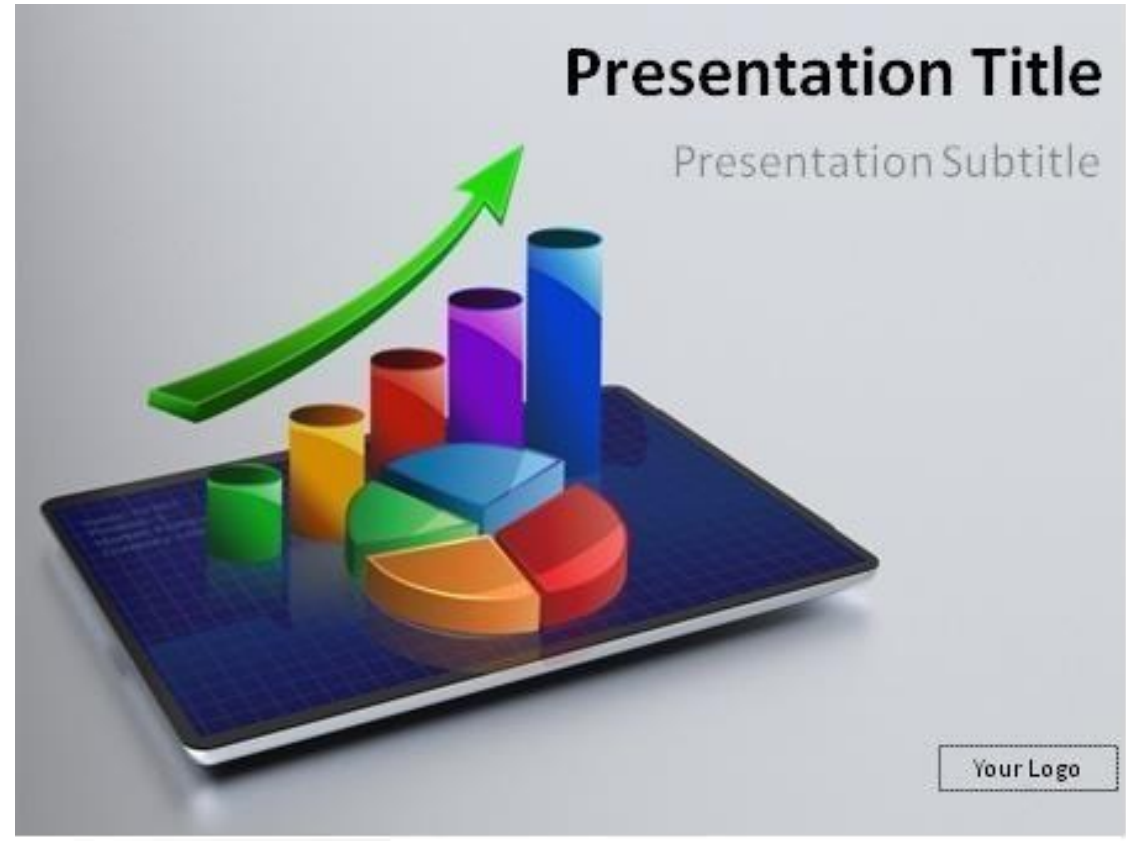
- Objects are displayed in wireframe outline that shows the overall shape and internal features of objects.



Presentation Graphics

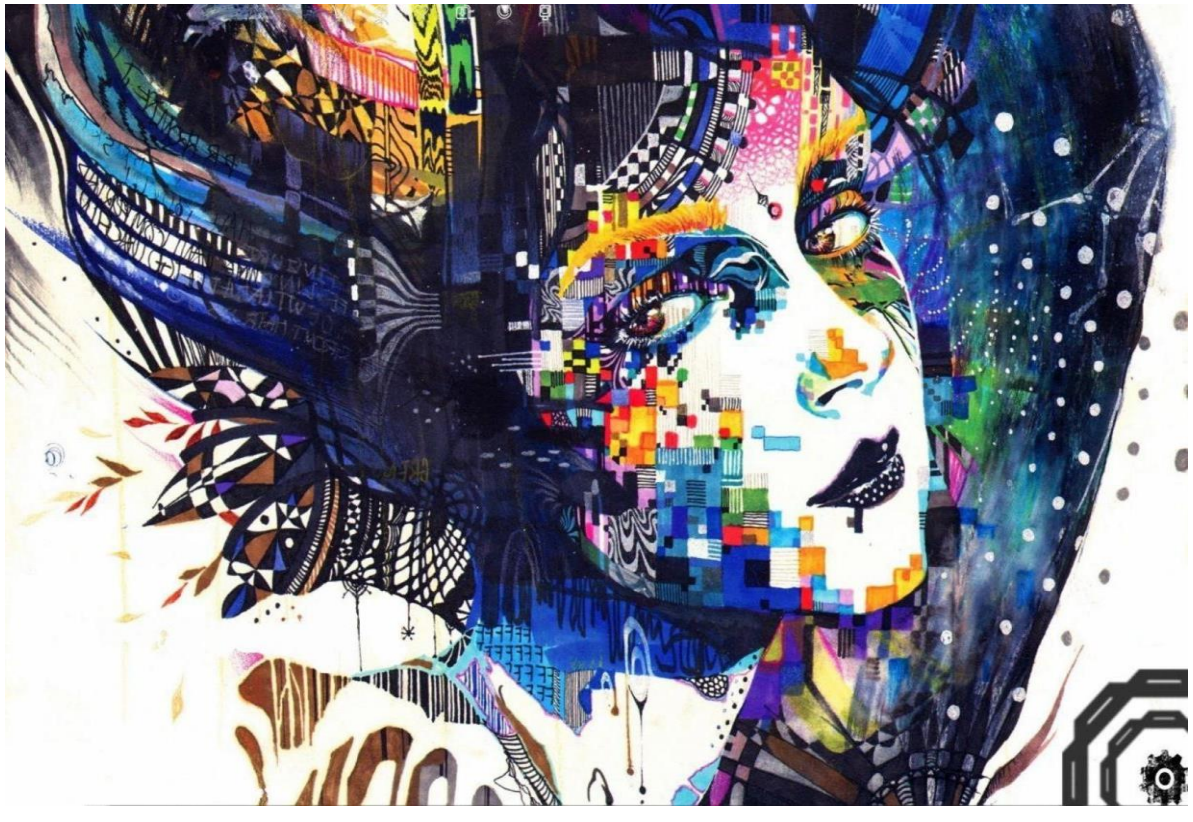
- Presentation Graphics is commonly used to summarize financial, statistical, mathematical, scientific and economic data for research reports, managerial reports and other types of reports.

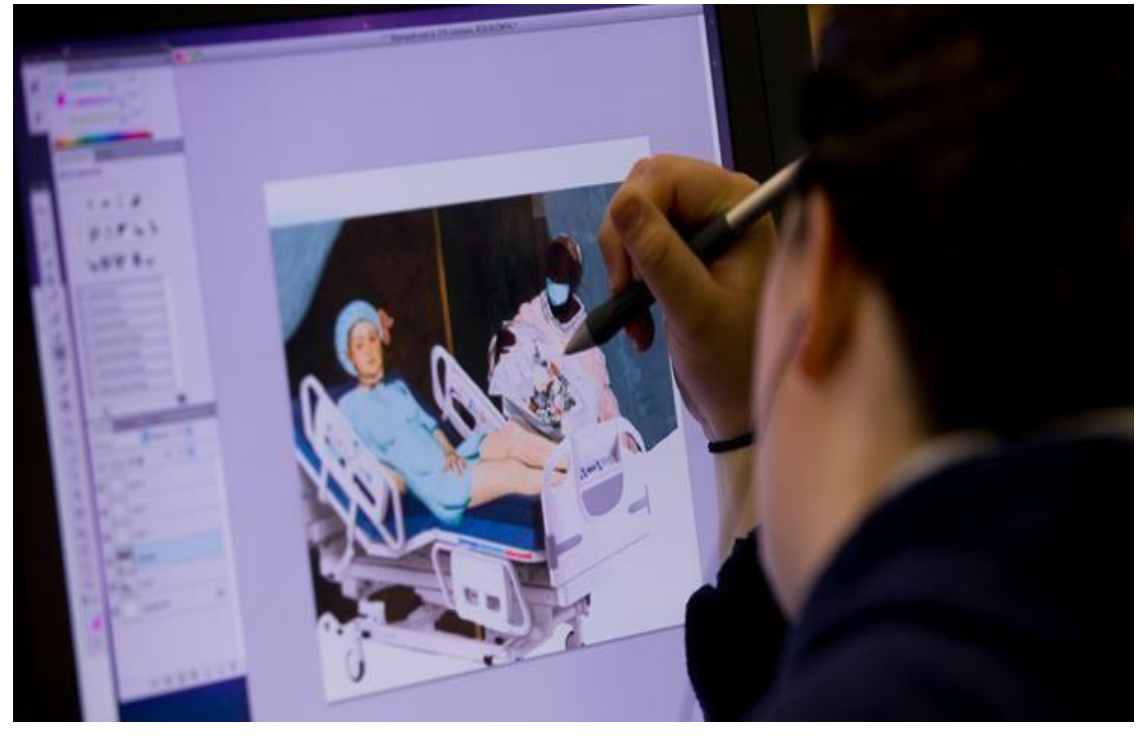
  - Typical examples are bar charts, line graphs, surface graphs, pie charts and other displays showing relationship between multiple variables.



Computer Art

- Computer graphics is used to generate arts.
- They are widely used in both fine art and commercial art applications.
- Fine art is drawn by artist hand and this kind of art is perfect to the artist skill.
- Artist use a variety of computer methods including special purpose hardware, artist's paints brush program, other paint packages, specially developed software.





Entertainment and Gaming

Computer graphics methods are new commonly used in making motion pictures, music videos and TV shows.

Images are drawn in wire-frame form and will be shaded with rendering methods to produce solid surfaces. Music videos use graphics in several ways.

Computer graphics are also used to introduce characters to movies like character in “Lord of the Rings”.

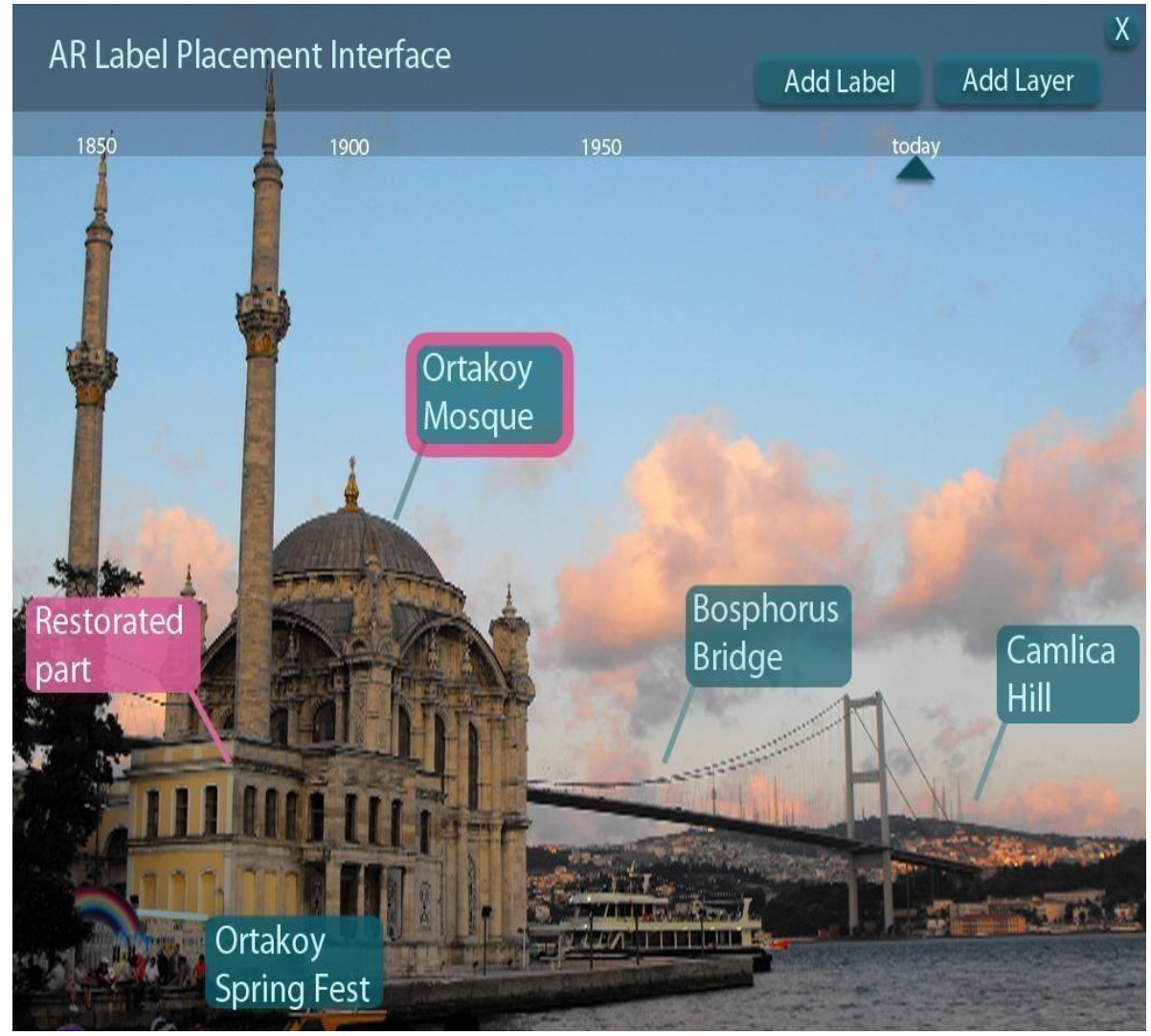
Education and Training….

Computer graphics is used in education and training for making it more effective and more illustrative.

Computer generated models of physical, financial, and economic systems are often used as educational aids. A student can learn surgery using data gloves and realistic computer graphics.

Visualization

- Visualization is the process of visually representing the data. To visualize large amount of information graphical computer systems are used.
- Some methods generate very large amount of data/information, analysis the property of the whole amount of data is very difficult. Visualization simplifies the analysis of data by using graphical representation.



Graphical User Interfaces (GUI)

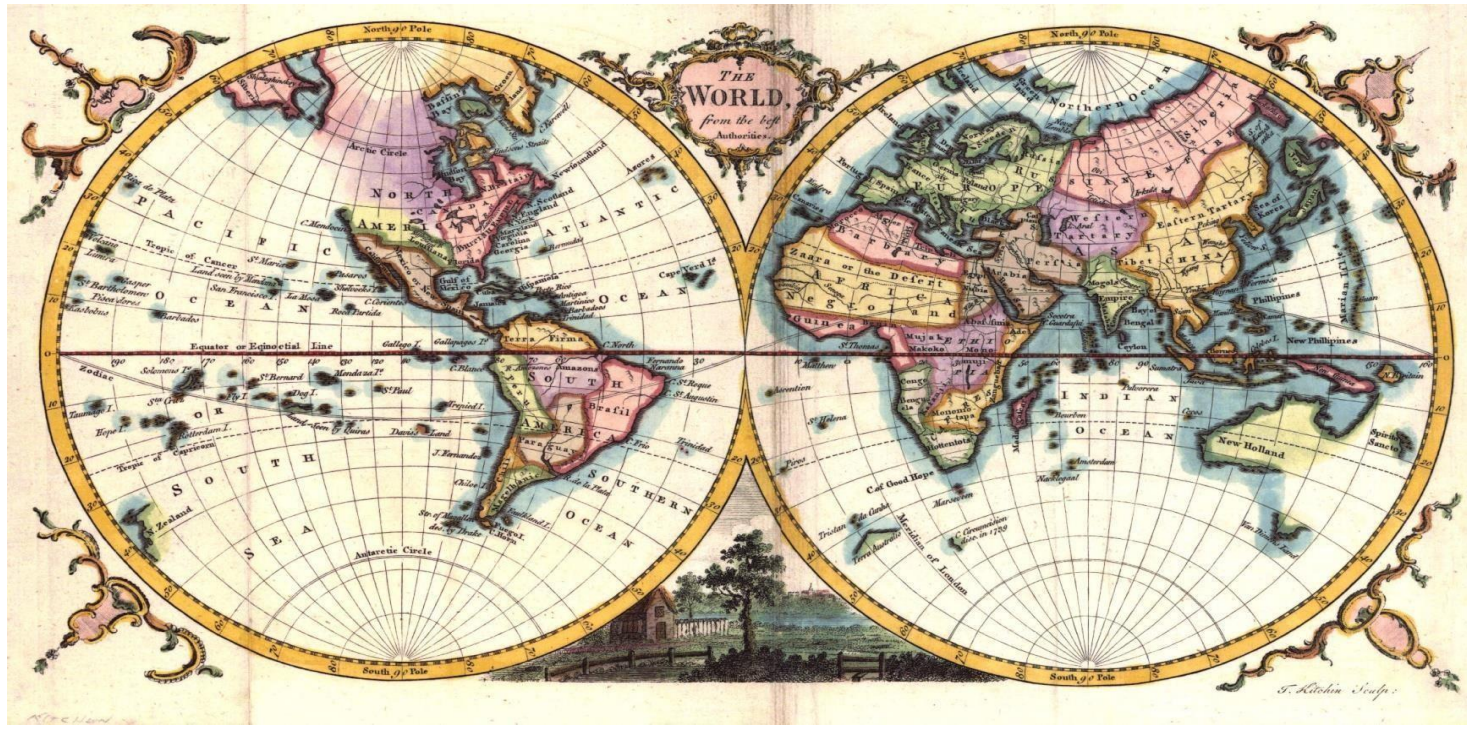
- GUIs have become key factors for the success of the software or operating system.
- GUI provides point-and-click facilities to allow users to select menu items, icons, and objects on the screen.
- Word processing, spreadsheet, and desktop-publishing programs are typical applications that take advantage of user-interface technique.

Simulation

- A representation of a problem, situation, etc. in mathematical terms, using a computer is called simulation.
- Computer Simulation is the process of mapping the real-world scenarios into mathematical model using computer graphics.
- Recently computer graphics is widely used to create simulated environment.
- E.g.; Robot Operation Simulation, Pilot Training, Military Training etc.

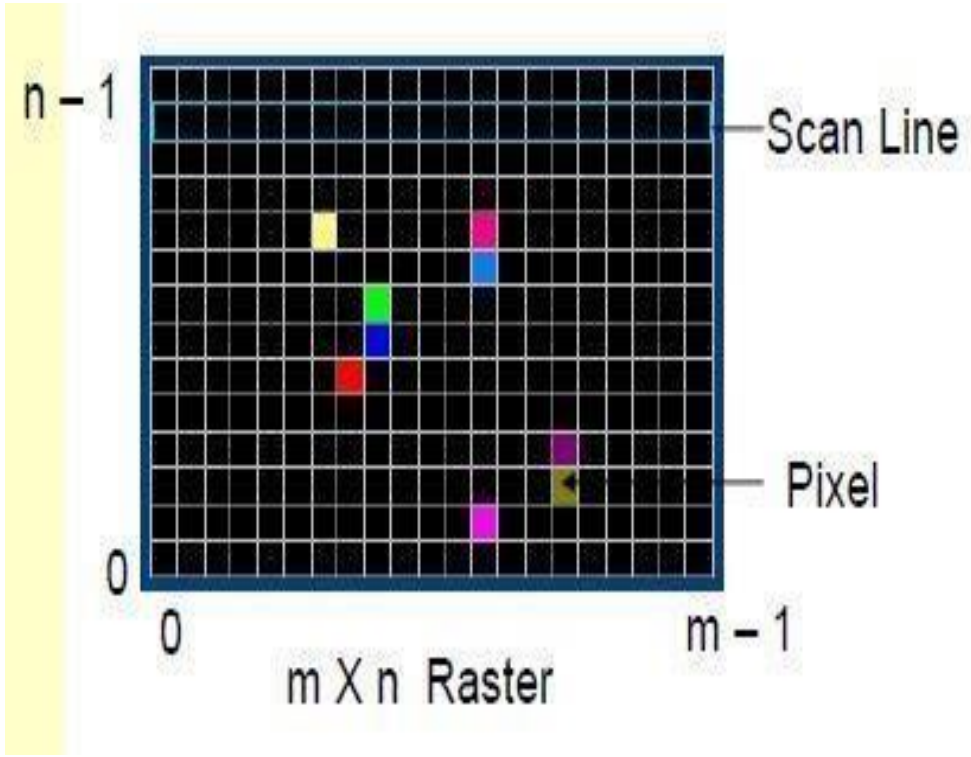
Cartography

- Cartography is the study and practice of designing maps using computer graphics.
- Computer graphics is used to produce both accurate and schematic representations of geographical and other natural phenomena from measurement data.
- Examples include geographic maps, exploration maps, for drilling and mining, oceanographic charts, weather maps etc.



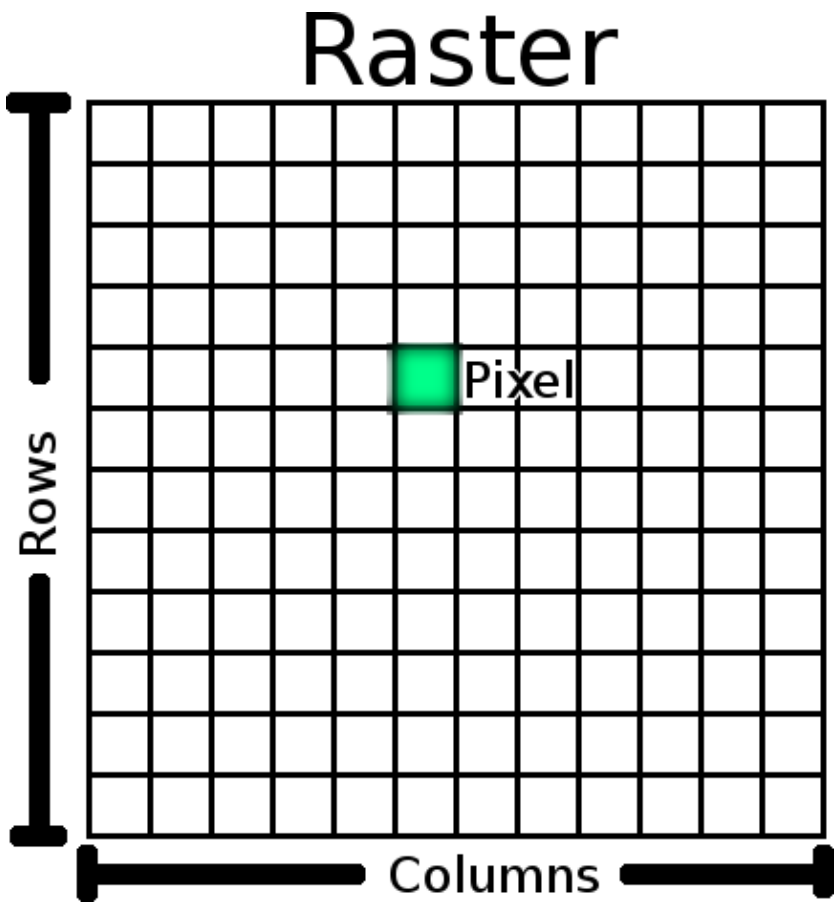
Basic Concept

- **RASTER :** A rectangular array of points or dots.
- **PIXEL** (picture element) **:**One dot or picture element of the raster
- **SCAN LINE :** A row of pixels
- **BITMAP :**ones and zeros representation of the rectangular array points on screen
  - Black and white :- bitmap
  - Pixmap :- color (colored raster image)



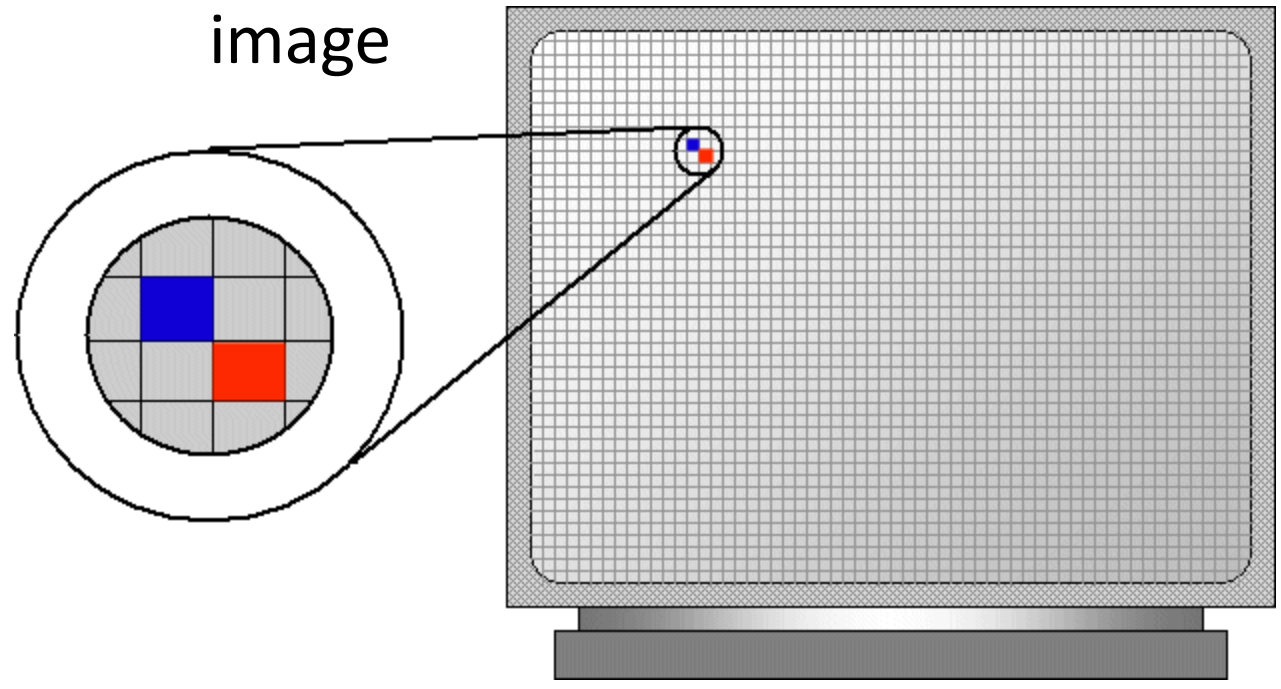
Raster

- A rectangular array of points or dots.



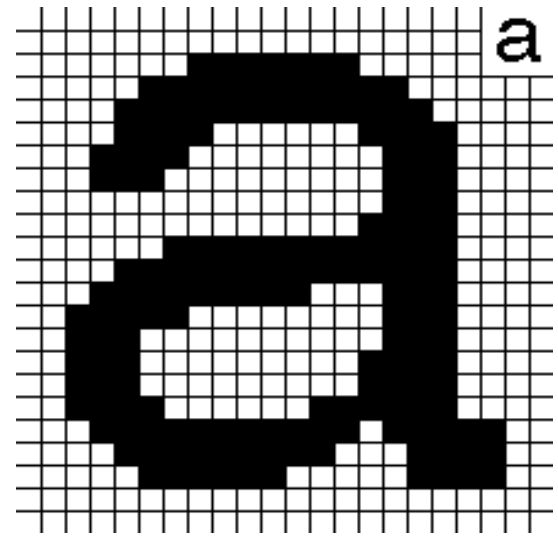
Pixel

- One dot or picture element of the raster
- The pixel (a word invented from "picture element") is the basic unit of programmable color on a computer display or in a computer image



Bitmap

- ones and zeros representation of the rectangular array points on screen
  - Black and white :- bitmap
  - Pixmap :- color (colored raster image)



Vector graphics

- **Vector graphics** is the creation of digital **images** through a sequence of commands or mathematical statements that place lines and shapes in a given two-dimensional or three- dimensional space

- Vector graphics are based on vectors, which lead through locations called control points or nodes.

- Each of these points has a definite position on the *x*- and *y*-axes of the work plane and determines the direction of the path; further, each path may be assigned various attributes, including such values as color, shape, curve, thickness, and fill

Vector

Vectors

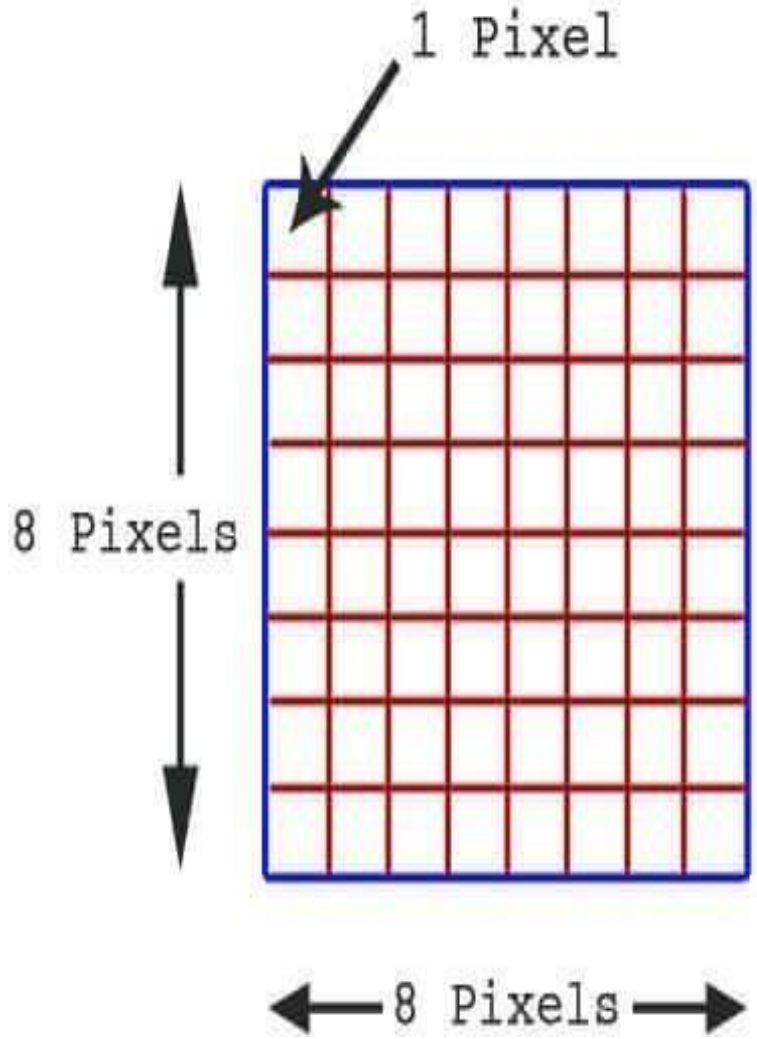
Vectors are based on mathematical formulas and can be scaled infinitely without any loss in quality. Every line and shape has a value that changes when the image expands.

Bitmaps

Bitmaps rely on a series of square blocks called pixels, arranged on a grid. The quality of the images depends on the amount of pixels per square inch. The more pixels, the better the quality.

Resolution

- The maximum number of points (pixel) that can be displayed without overlap on a CRT is referred to as the resolution.
- It is also defined as the number of points per unit of measure (per centimeter or per inch) that can be plotted horizontally and vertically.
- Resolution is defined as the maximum member of points that can be displayed horizontally and vertically without overlap on a display device.



Standard way of writing Resolution

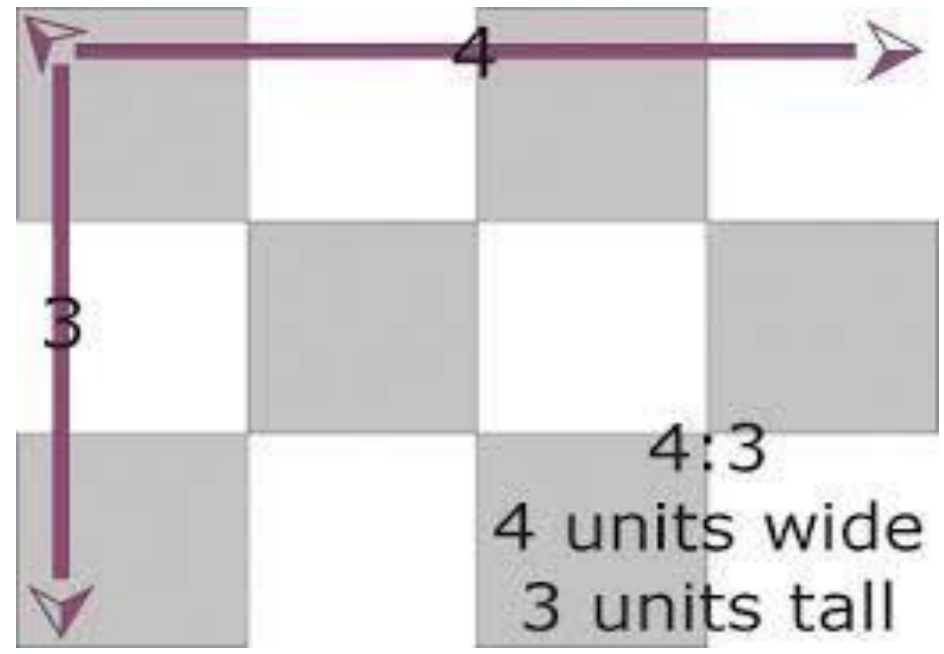
Resolution = 8 x 8 Pixels

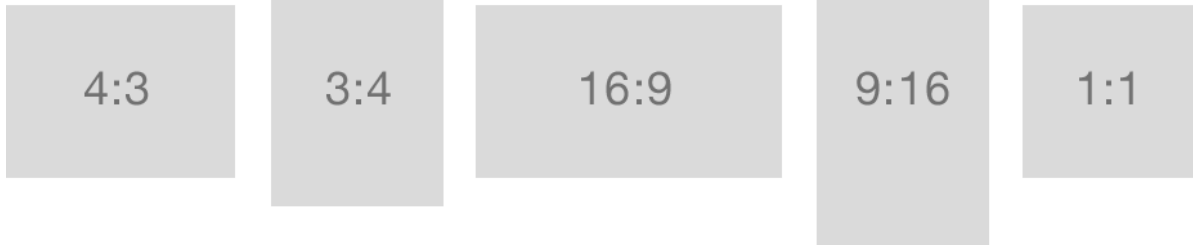
= 64 Pixels

Actual total Resolution

Aspect Ratio

- The **aspect ratio** of an image describes the proportional relationship between its width and its height.
- It is commonly expressed as two numbers separated by a colon, as in *16:9*.
- For an *x*:*y* aspect ratio, no matter how big or small the image is, if the width is divided into *x* units of equal length and the height is measured using this same length unit, the height will be measured to be *y* units.



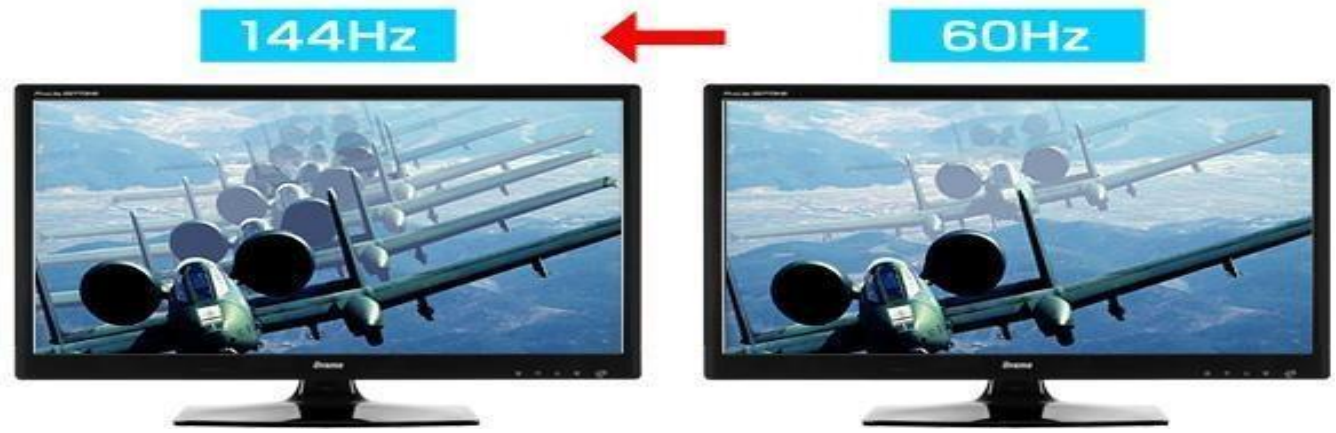


Persistence

- It means how long they continue to emit light after the electron beam is removed.
- Persistence is defined as the time it takes the emitted light from the screen to decay to one-tenth of its original intensity.
- Lower persistence phosphors require higher refresh rates to maintain a picture on the screen.
- A phosphor with lower persistence is useful for animation and a higher–persistence phosphor is useful for displaying highly complex static picture.
- Graphics monitor are usually constructed with the persistence 10 to 60 microseconds.

Refresh Rate

- The number of times the screen is redrawn each second.
- Higher refresh rates mean less flicker on the screen, which translates into less eyestrain.



Input Devices

Mouse

- A mouse is a small hand-held device used to position the cursor on the screen.
  Types
    - Mechanical mouse
    - Optical mouse

Touch Screen

- Touch panels are a sensitive surface that is used to point directly.
- The panel can be touched by finger or any other stylus.
- A basic touch panel senses voltage drop when a user touches the panel.
  It knows where the voltage has dropped and accordingly calculates the touch position.

Light Pen

- Light pens have the advantage of 'drawing' directly onto the screen, but this can become uncomfortable, and they are not as accurate as digitizing tablets

Data Glove

- Constructed with a series of sensors that can detect hand and finger motions. Electromagnetic coupling between the three pairs of coil is used to provide information about the position and orientation of hand.

Tablet (Digitizer)

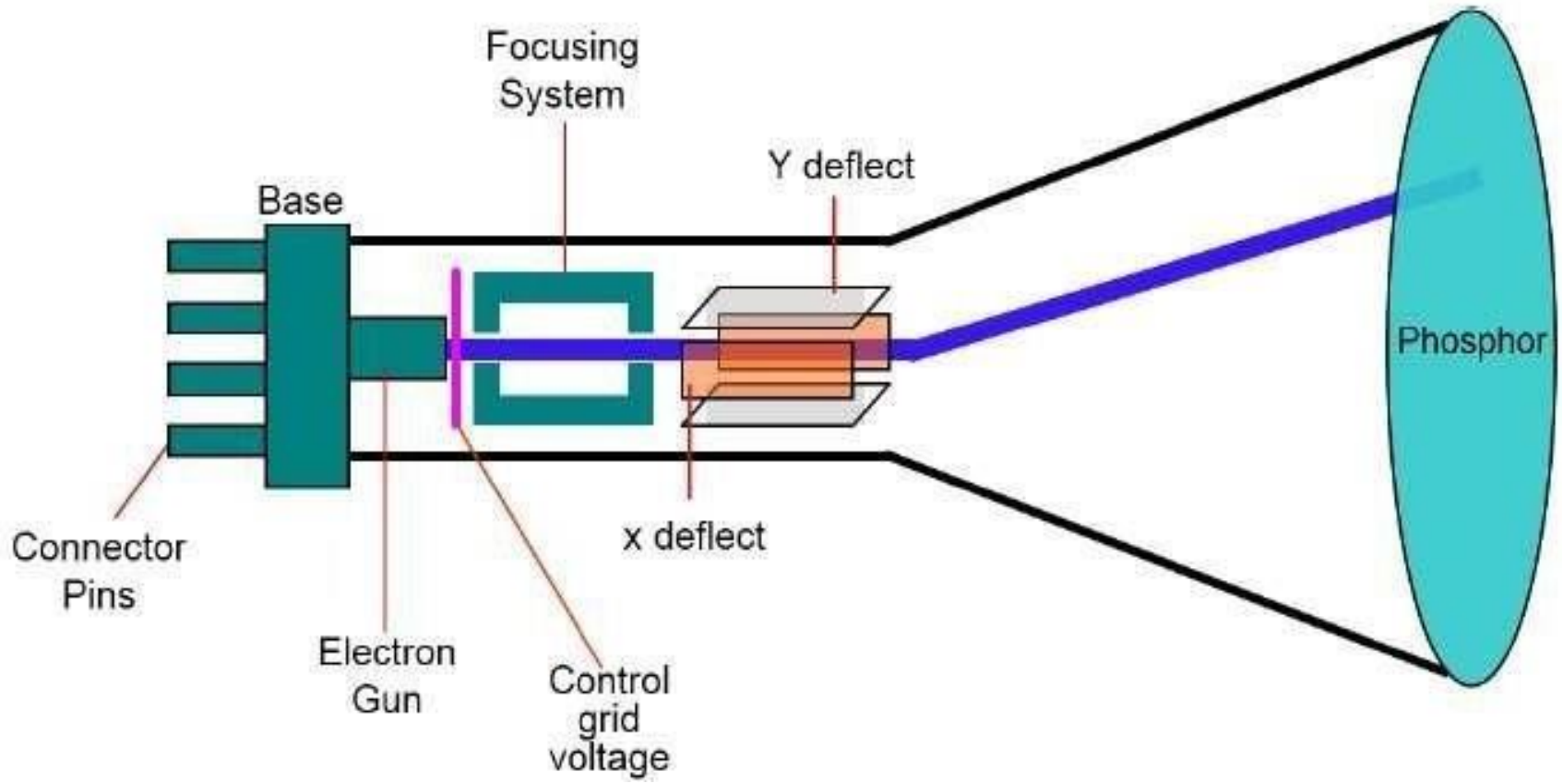
- No keyboard, no mouse. Instead, you have an LCD screen and a stylus
- You don't need to convert handwriting to text
- Tablets are gaining popularity as a replacement for the computer mouse as a pointing device

Bar Code Reader

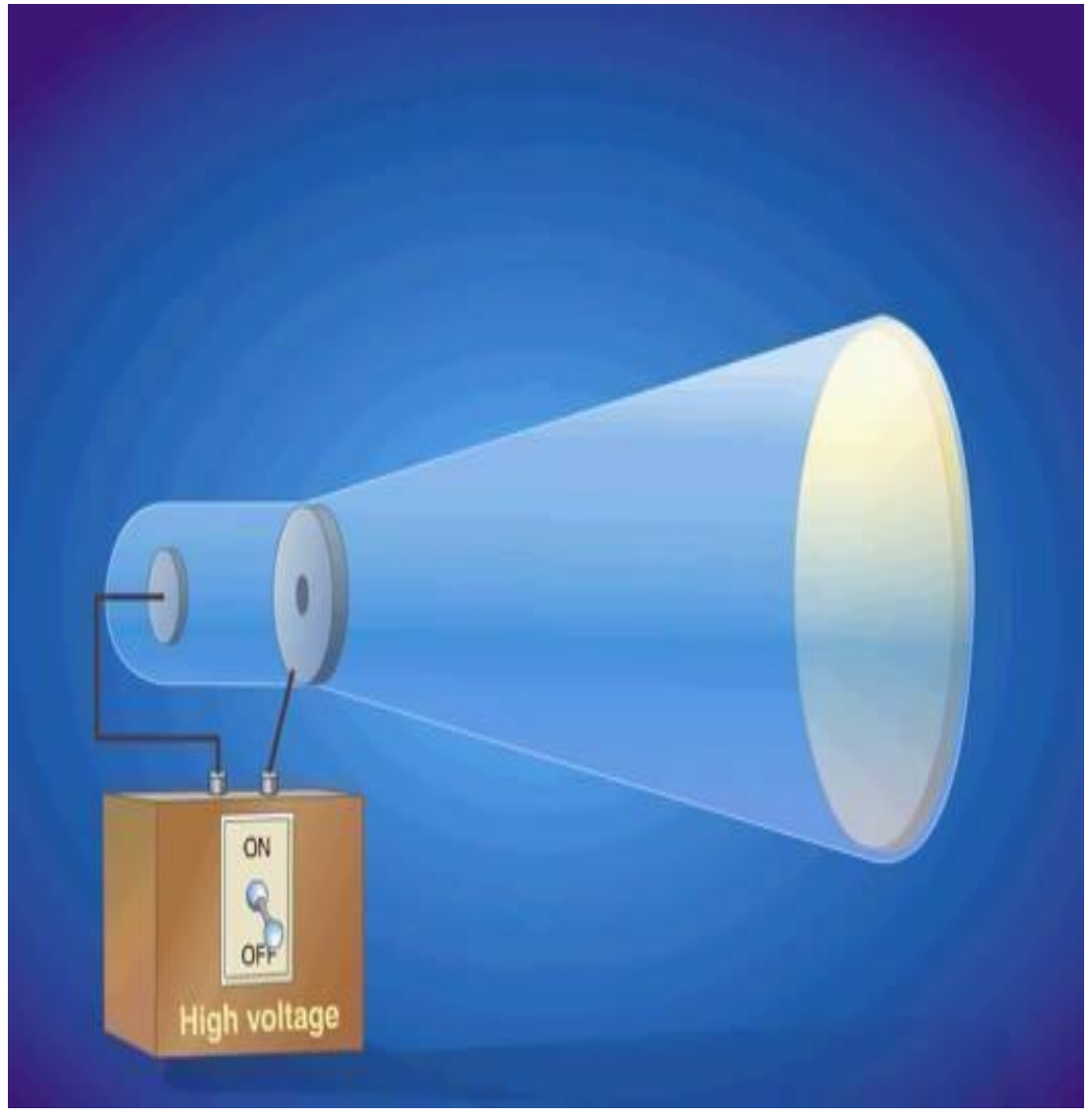
- A bar code is a machine-readable code in the form of a pattern of parallel vertical lines. They are commonly used for labeling goods that are available in supermarkets, numbering books in libraries etc.
- These codes are sensed and read by a photoelectric device called bar code reader that reads the code by means of reflected light. The information recorded in a bar code reader is fed into the computer, which recognizes the information from the thickness and spacing of bars.

Cathode Ray Tube

- The cathode ray tube (CRT) is a tube containing one or more electron guns (a source of electron) and a fluorescent screen used to view images. A beam of electrons (cathode rays) emitted by an electron gun, passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor-coated screen. When the electrons hit the screen, the phosphor emits visible light.
- Because the light emitted by the phosphor decays very rapidly with time, so the entire picture must be refreshed (redrawn) many times per second by quickly directing the electron beam back over the same points. Therefore, also called a *refresh CRT.*

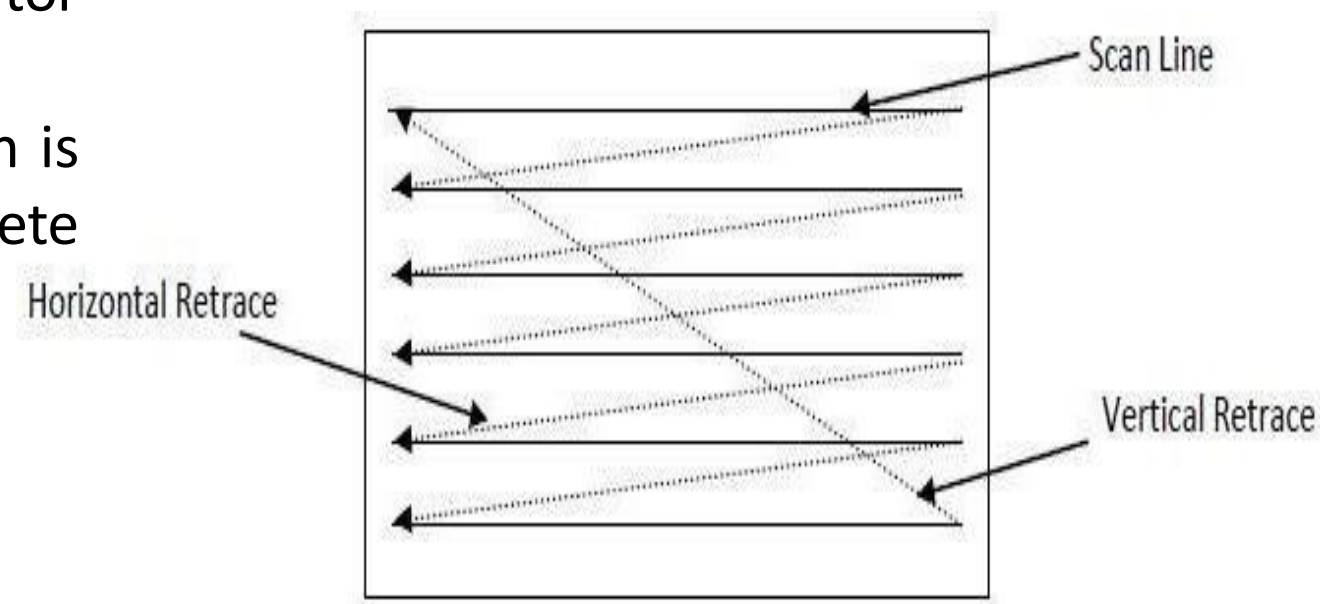


- There are two sets of weakly charged deflection plates with oppositely charged, one positive and another negative. The first set displaces the beam up and down and the second displaces the beam left and right.
- When electrons strike on phosphor coating, the phosphor then emits a small spot of light at each position contacted by electron beam. The glowing positions are used to represent the picture in the screen.
- The amount of light emitted by the phosphor coating depends on the no of electrons striking the screen. The brightness of the display is controlled by varying the voltage on the control grid.



Raster-Scan Displays

- The most common type of graphics monitor employing a CRT is the raster-scan display.
- In raster scan approach, the viewing screen is divided into a large number of discrete phosphor picture elements, called pixels.
- Row of pixels is called the scan line.



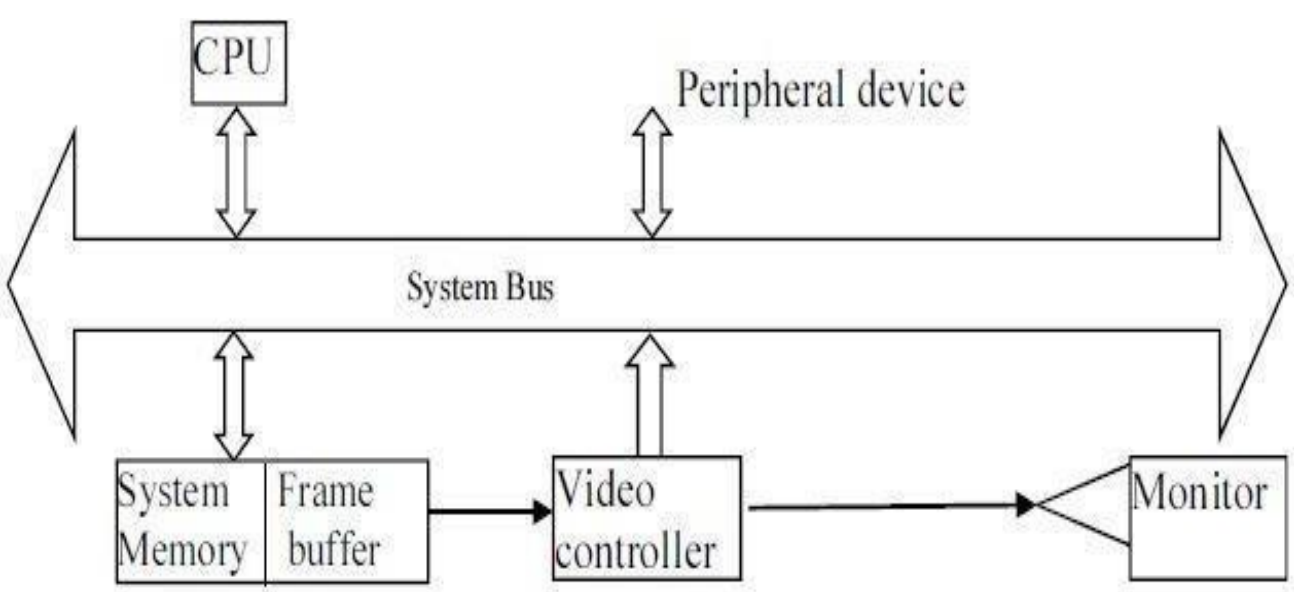


Figure: A simple Raster System.

Architecture of Raster Scan System

- The raster graphics systems typically consists of several processing units. CPU is the main processing unit of computer systems. Besides CPU, graphics system consists of a special purpose processor called video controller or display processor. The display processor controls the operation of the display device.
- A fixed area of system memory is reserved for the frame buffer. The video controller has the direct access to the frame buffer for refreshing the screen.

- In a random scan display unit, electron beam directed towards only to the parts of the screen where a picture is to be drawn.
- Random-scan monitors draw a picture one line at a time and for this reason are also referred to as vector displays. Random scan system uses an electron beam which operates like a pencil to create a line image on the CRT.

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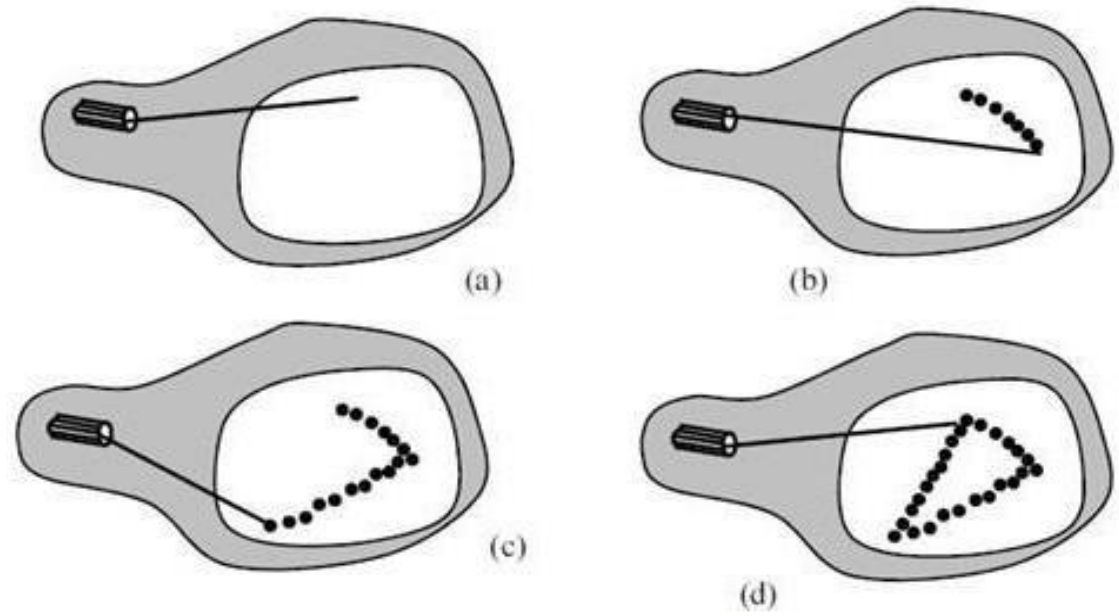


Figure: Random Scan Display

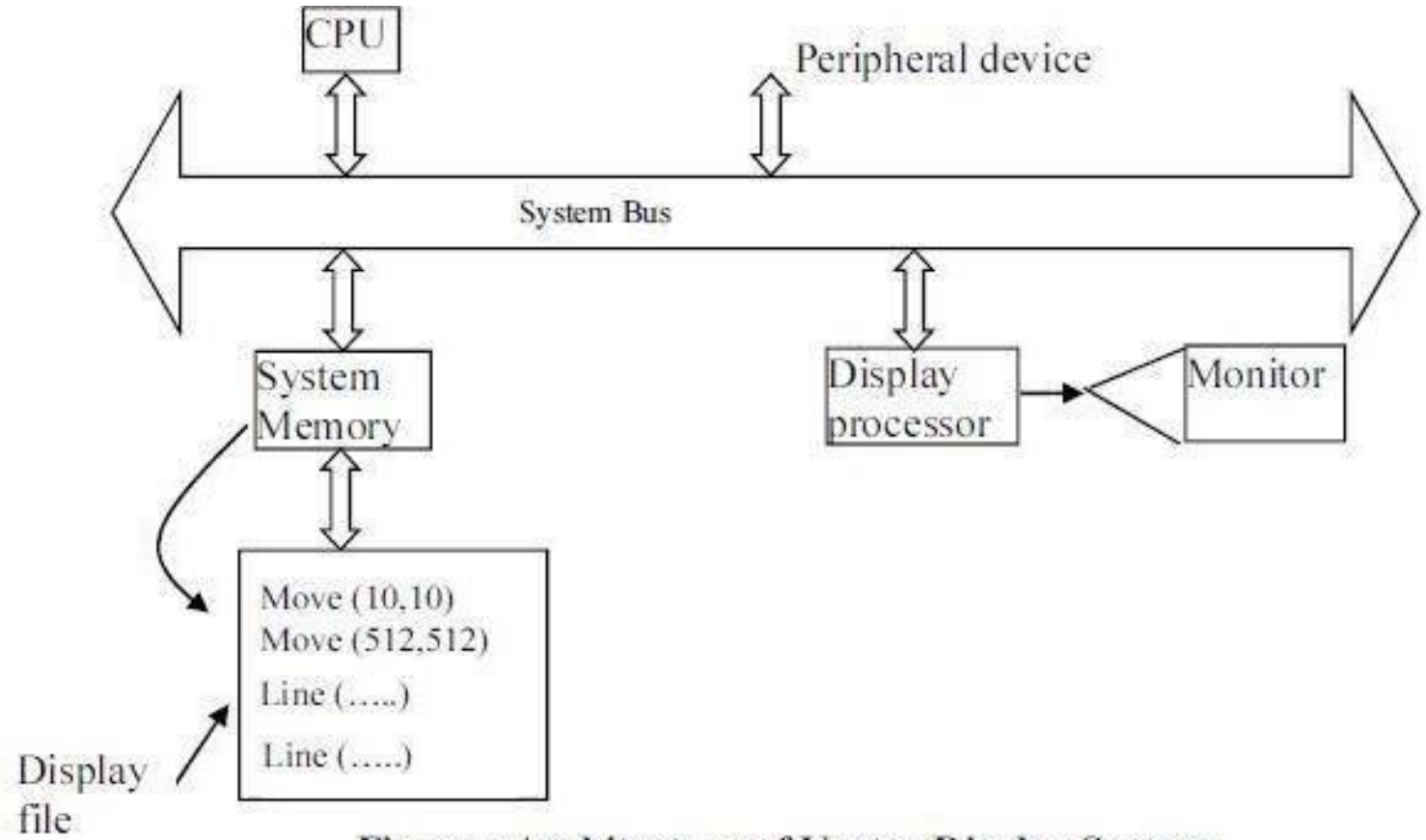


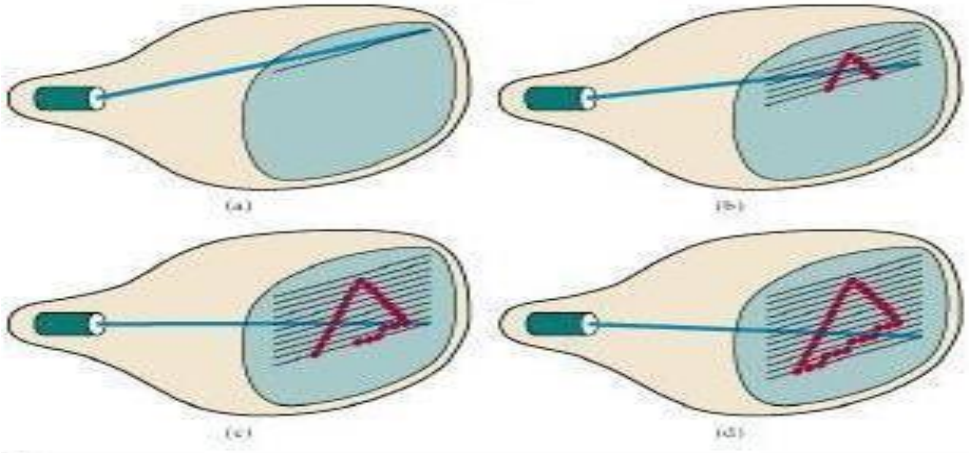
Figure : Architecture of Vector Display System

Architecture of Random Scan Display.....

- Vector display system consists of several units along with peripheral devices. The display processor is also called as graphics controller.
- Graphics package creates a display list and stores in systems memory (consists of points and line drawing commands) called display list or display file.
- Graphics are drawn on a vector display system by directing the electron beam along component line.

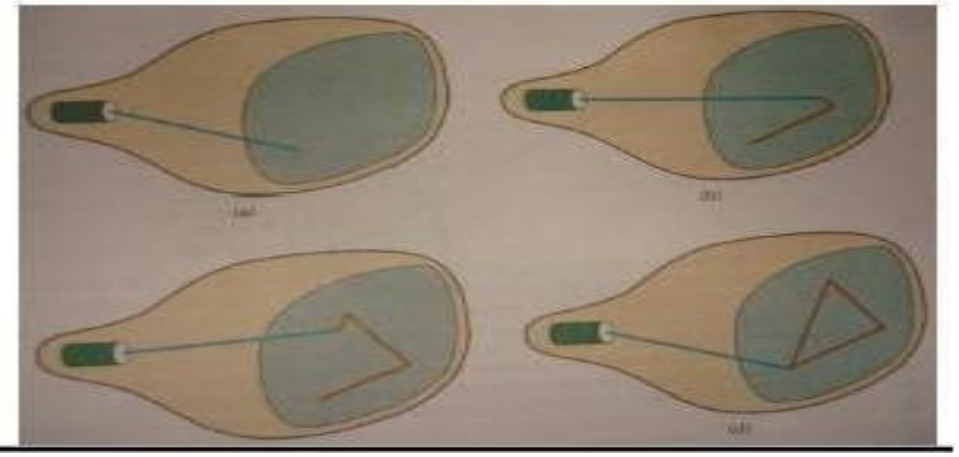
Raster Scan

- Electron beam swept across the screen ,one row at a time from top to bottom. e.g. television



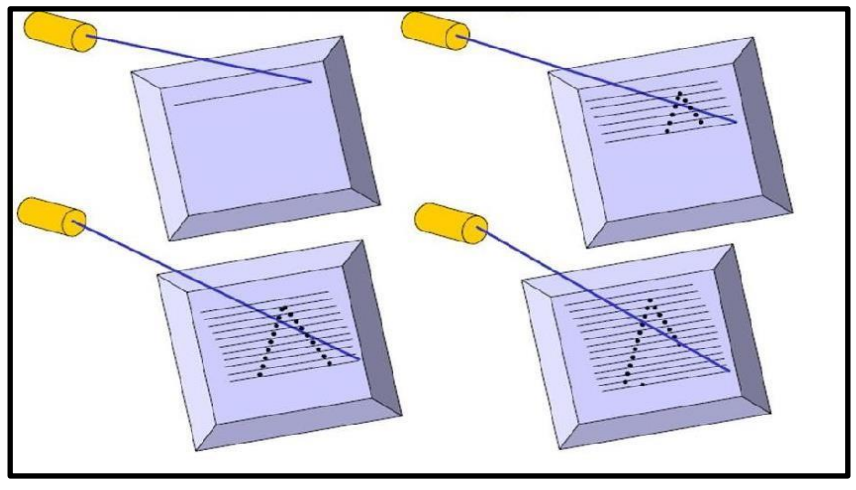
Random or vector Scan

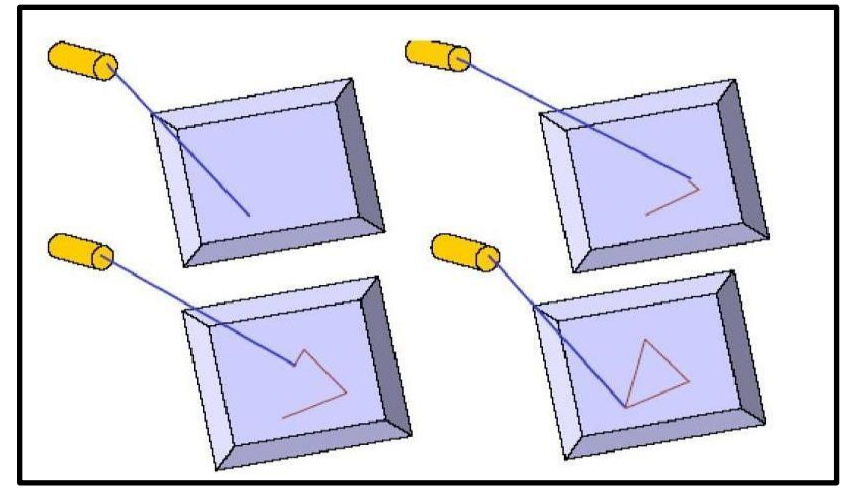
- Electron beam directed only to parts of the screen where a picture is drawn. e.g. pen plotter



Raster VS Random

Raster	Random
1.Refresh Rates : Refreshing on raster scan display is carried out at the rate of 60 to 80 frames per second. Sometimes, refresh rates are described in units of cycles per second, or ***Hertz (Hz)***, where a cycle corresponds to one frame.	***1.Refresh Rates :*** Generally, refreshing on random-scan display is carried out at the rate of 60 frames per second. Refresh rate on a random-scan system depends on the number of lines to be displayed. Picture definition is now stored as a set of line-drawing commands in an area of memory, referred to as the *refresh display file*.
2.Applications: i. For the realistic display of scenes containing subtle shading and color patterns. ii. Home television sets and printers are examples of raster-scan systems.	***2.Applications:*** i. Random-scan systems are used in *line-drawing applications*. ii. Vector displays generally used to produce graphics with higher resolution.

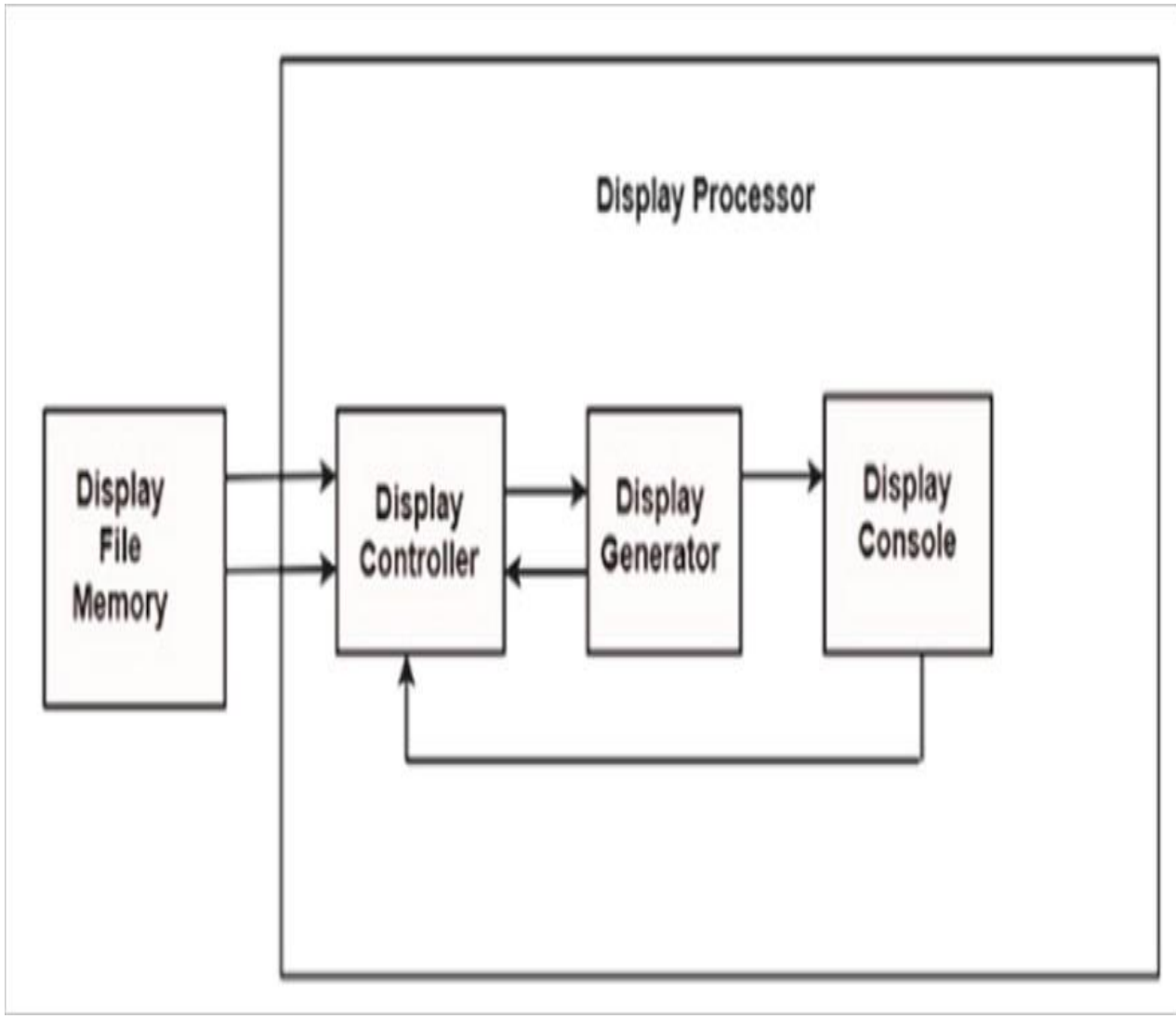




Display Processor

- Display Processor is the interpreter or a hardware that converts display processor code into picture.
- The Display Processor converts the digital information from CPU to analog values.
- The main purpose of the Digital Processor is to free the CPU from most of the graphic chores.
- The Display Processor digitize a picture definitions 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.

Display Processor



Features of Display Processor

- Display processors includes functions such as generating various line styles, displaying color area and performing transformations and manipulations on display object.
- Display Processor was used before the GPU (Graphics Display Processor).
- Video Controller is the most widely used Display device that is based on CRT (Cathode Ray Tube).
- In addition with the system memory, Display Processor have a separate memory area.

1. Display File Memory

It is used to display the pictures on the screen. The Display File Memory identifies the different graphics objects or entities. All the pixel values that are to be showed on the screen are there in the display File memory.

2. Display Controller

The Display Controller handles the flow instructions in the display processor. It is responsible for handling the interrupt and to maintain the timings between their executions. Interpretation of the instructions is also performed by the Display Controller.

3. Display Generator

Display Generator is used to generate characters and shapes on the screen. This displays the shapes and characters according to the input we give in it. In short, the Display Generator is used for generating curves and characters on the screen.

4. Display Console

Display Console is a combination of a display device and an input device. This is the part of the Display Processor which shows the output on the screen. The Cathode Ray Tube comes under the Display Console. In common terms, the display console is the screen on which you see all your graphical outputs.

Numerical

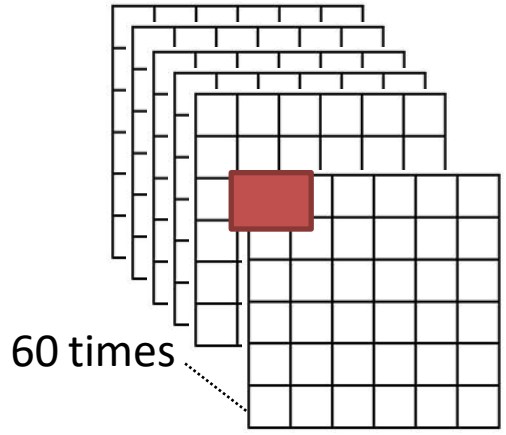
Q.N.1:. In case of raster system with resolution 1024 X 1280, how many pixel could be accessed per second in the system by a display controller at a rate of 60 frames per second?
what is accessed time per pixel in this system ?

Ans :

1. Pixel accessed :

= 1024 X 1280 X 60 pixel can be accessed in this system

2. Access time per pixel:
= 1/(1024 X 1280 X 60)
= 12.71ns



Q.N.2.: How long would it takes to load a 640 X 480 frame buffer with 12 bit per pixels if 10^5 bits can be transferred per second.

Ans :

total size of frame buffer :
= 640 X 480 X 12

it takes = $(640 \times 480 \times 12)/10^5$
= 36.864 sec

**Formula:*

*Required size of frame= Resolution or total no. of pixel **X** no. of bit per pixel on screen*

Graphical Softwares

Graphics software is a type of computer program that is used to create and edit images.
There is a wide range of graphics software available on the market, ranging from simple programs that allow users to create and edit basic images, to complex tools that can be used to create detailed 3D models and animations.
Some of the most popular graphics software programs include Adobe Photoshop, Corel Painter, and Autodesk Maya.

Adobe Photoshop is a popular graphics software used by photographers and graphic designers.
Adobe Illustrator is another popular graphics software used by graphic designers, especially for creating vector illustrations.
CorelDRAW is a graphics software used by both professionals and hobbyists.
GIMP is a free and open source graphics software with capabilities similar to Photoshop.
Inkscape is a free and open source vector graphics software used by graphic designers and illustrators.

Components of Graphical Software

1. **Image editors**: These are the tools that you use to create or edit your graphic images. Common image editors include Photoshop, Illustrator, and Inkscape.
2. **Vector graphics editors**: These are the tools that you use to create or edit vector graphics. Common vector graphics editors include CorelDRAW and Inkscape.
3. **3D modeling software**: This is the software that you use to create three-dimensional models. Common 3D modeling software includes Maya, 3ds Max, and Cinema 4D.
4. **Animation software**: This is the software that you use to create animations. Common animation software includes Adobe After Effects, Apple Motion, and Autodesk Maya.
5. **Video editing software**: This is the software that you use to edit videos. Common video editing software includes Adobe Premiere Pro, Apple Final Cut Pro, and Avid Media Composer.

Graphical Software Standards

The primary goal for the graphics software's standard is portability whenever a package is designed with some standards for the computer graphics, then the software can be moved from one hardware system to another hardware system in an easy way and also be implemented more easily.
Without the standards for the programs, it becomes a complex and even impossible task to transfer the programs which are designed for a particular hardware

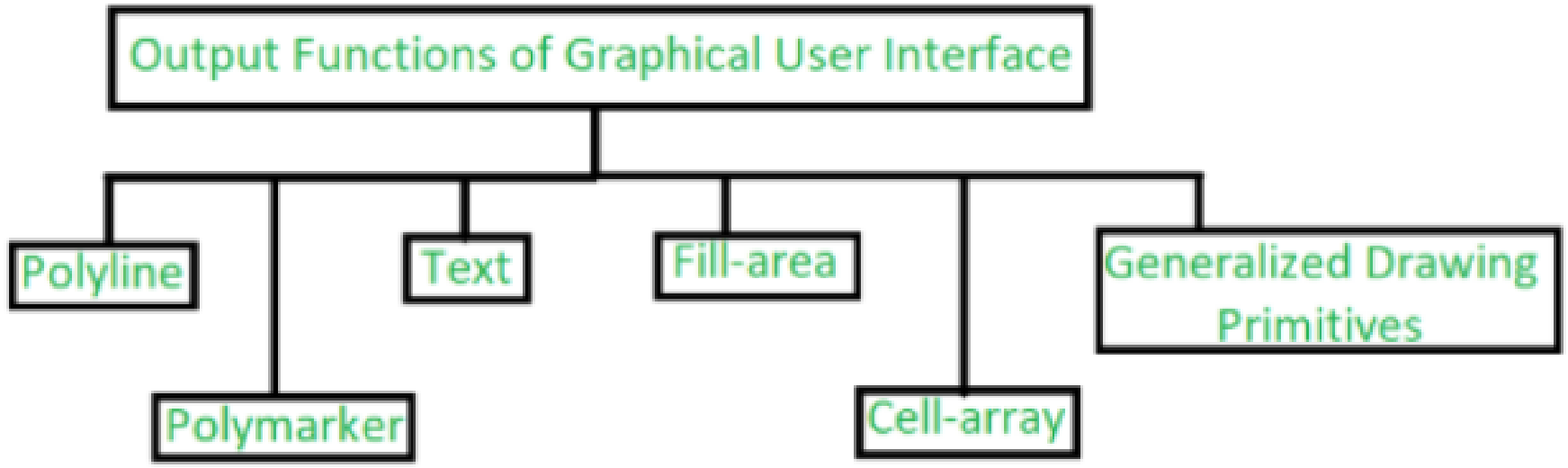
2 standards are there for graphical software:

1. GKS (Graphical Kernerl System)
2. PHIGS (Programmer's Hierarchical Interactive Graphics Standard)

GKS (Graphical Kernel System)

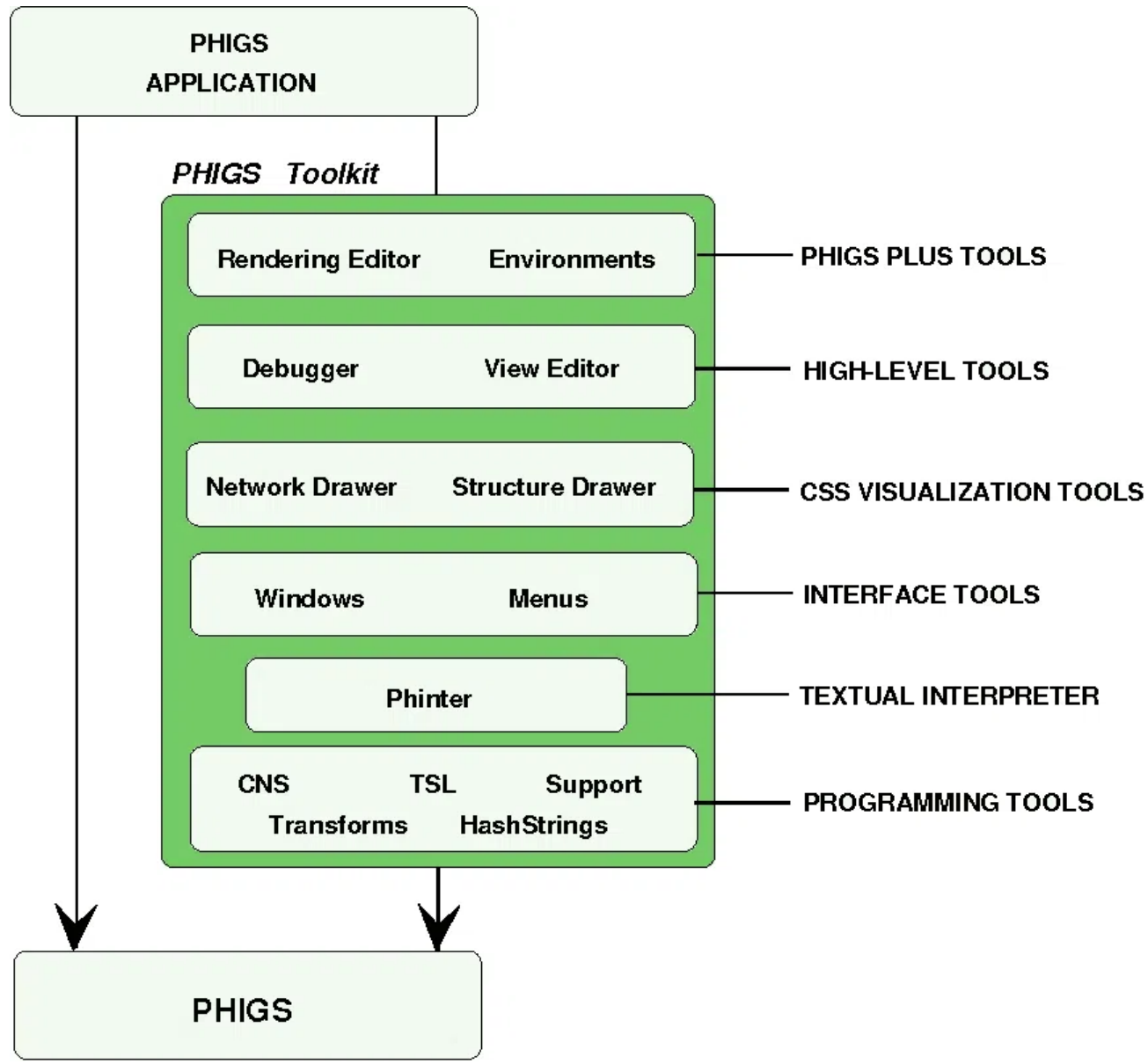
GKS is recognized as one of the first graphics software standards by the ISO that manages the top-level two-dimensional three-dimensional standards related to computer study.

Graphical kernel system has a 2-dimensional view which is related to the six of the output functions used



PHIGS (Programmer's Hierarchical Interactive Graphics Standard)

PHIGS is the second standard developed in, computer graphics for the development of computer systems and software, it is known as an advancement to the previous standard because it supports more increased capabilities for the modeling of objects, better picture manipulation and other color specification guides.



1. Which devices provides positional information to the graphics system ?

a) Input devices
b) Output devices
c) Pointing devices
d) Both a and c

2. The number of pixels stored in the frame buffer of a graphics system is known as

a) Resolution
b) Depth
c) Resalution
d) Persistence

3.In graphical system, the array of pixels in the picture are stored in

a) Memory
b) Frame buffer
c) Processor
d) All of the mentioned

4. Heat supplied to the cathode by directing a current through a coil of wire is called

a) Electron gun
b) Electron beam
c) Filament
d) Anode and cathode

5. The maximum number of points that can be displayed without overlap on a CRT is referred as

a) Picture
b) Resolution
c) Persistence
d) Neither b nor c

6. The devices which converts the electrical energy into light is called

a) Liquid-crystal displays
b) Non-emitters
c) Plasma panels
d) Emitters

7. The process of digitizing a given picture definition into a set of pixel-intensity for storage in the frame buffer is called

a) Rasterization
b) Encoding
c) Scan conversion
d) True color system

8. In LCD, the refresh rate of the screen is

a) 60 frames/sec
b) 80 frames/sec
c) 30 frames/sec
d) 100 frames/sec

9. The primary output device in a graphics system is_____

a) Scanner
b) Video monitor
c) Neither a nor b
d) Printer

10. On a black and white system with one bit per pixel, the frame buffer is commonly called as

a) Pix map
b) Multi map
c) Bitmap
d) All of the mentioned

11. _____ allows screen positions to be selected with the touch of a finger.

a) Touch panels
b) Image scanner
c) Light pen
d) Mouse

12. Aspect ratio means

a) Number of pixels
b) Ratio of vertical points to horizontal points
c) Ratio of horizontal points to vertical points
d) Both b and c

13. The device which is designed to minimize the background sound is

a) Microphone
b) Digitizers
c) Data glove
d) Joy stick

14. Color information can be stored in

a) Main memory
b) Secondary memory
c) Graphics card
d) Frame buffer

15. With 3 bits per pixel, we can accommodate 8 gray levels. If we use 8 bits per pixel then what is the value of gray levels?

a) 18 gray levels
b) 128 gray levels
c) 256 gray levels
d) No color

16. In color raster system, the number of color choices available depends on

a) colors in frame buffer
b) Amount of storage provided per pixel in frame buffer
c) RGB color
d) Neither a nor b