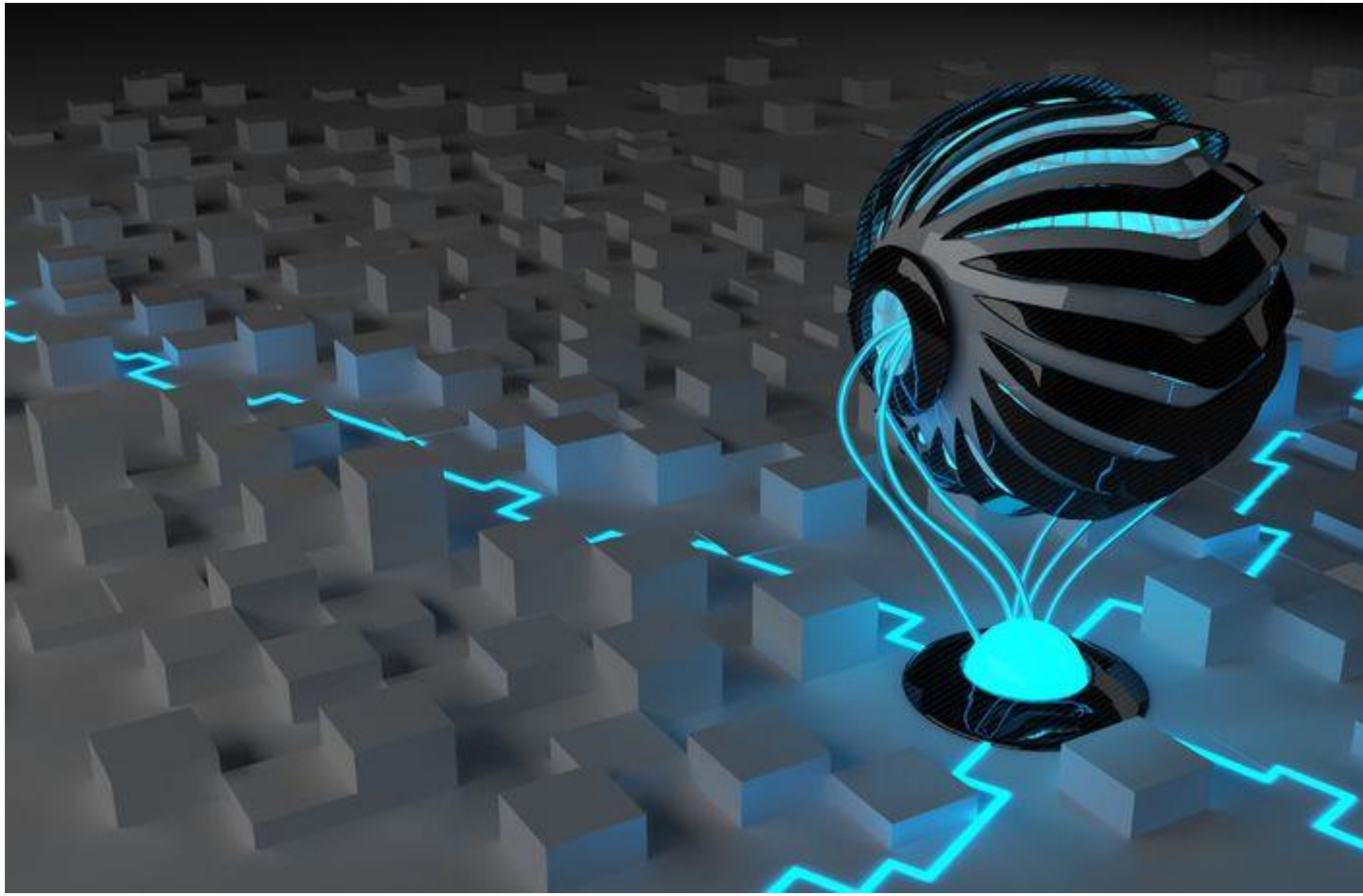
Computer Graphics and Visualization

Chapter 1

Introduction and application



Introduction and application [4 hours]

CONTENTS

History of computer graphics

- Overview of Graphic Systems
  - Video Display Devices: Raster-Scan Displays, Random-Scan Displays, Flat Panel Displays, 3D viewing Devices
  - Graphics Software and tools: Coordinate Representations, Graphics Functions, Software Standards, PHIGS Workstations, DirectX, OpenGL, WebGL, Maya, Blender, Unity
- Graphics pipeline
  - Two-dimensional viewing pipeline
  - Three-dimensional viewing pipeline
- Applications in various fields like medicine, engineering, art, uses in augmented and virtual realism.

Introduction

- **Computer Graphics**
  - Computer Graphics is a field related to the generation of graphics using computers
  - It studies method for digitally synthesizing and manipulating visual content
  - Broad sense: "roughly everything on computers which is not text or sound"
- Computer graphics refer different things in different contexts:
  - **Images,** scenes that are generated by a computer
  - **Tools** used to make such pictures, software and hardware, input/output devices
  - The **whole field of study** that involves these tools and the pictures they produce

- Computer graphics includes the **creation, storage, and manipulation** of images of objects
- These objects come from diverse fields **such as physical, mathematical, engineering, architectural, abstract structures and natural phenomenon**
- Examples: photographs, drawings, line art, mathematical graphs, line graphs, charts, diagrams, typography (the art of arranging letters and text in a way that makes visually appealing to the reader.), numbers, symbols, geometric designs, maps, engineering drawings, or other images

Main tasks:

- **Imaging**: Formation of an image
  - representation of 2D images
- **Modelling**: Representing 3D images
- **Rendering**: Rendering or image synthesis is the process of generating a photorealistic or non-photorealistic image from a 2D or 3D model by means of a computer program
- **Animation**: Stimulating changes over time
  - That is the movement on the screen of the display device created by displaying a sequence of **still images**

- Computer Graphics is a modern and expansive field in computer science
- **John Whitney** was regarded as a pioneer and one of the early computer animators throughout the 1940s and 1950s
- **Verne Hudson and William Fetter**, computer graphics researchers at Boeing, came up with the term in 1960
- It is frequently referred to as **CG** or, more commonly, as computer-generated imagery (**CGI**) in the context of movies
- Until 1980s computer graphics was a small, specialised field - expensive hardware, only few easy to use graphics based application program

History

- **1950** First Graphics Images were created by Ben Laposky
- **1951** CRT monitors on Main Frame computer were introduced
- **1959** CAD was used to design cars
- **1960** Term “computer graphics” is coined by William A. Fetter at Boeing
- **1961** First video game named “Space War “developed
- **1963** Ivan Sutherland develops Sketchpad, the first Computer-Aided Drafting and Design (CADD) package
- **1963** First Hidden Line and Hidden surface removal algorithms developed

- **1965** DDA algorithm developed by Jack Bresenham
- **1973** The entertainment feature film “Westworld” makes the first use of 2D animation
- **1981** IEEE Computer Society starts publishing a new journal, Computer Graphics and Applications
- **1982** Autodesk is founded and AutoCAD was released.
- **1992**: Silicon Graphics Inc. (SGI) releases the Open Graphics Library (OpenGL)
- **1995**: Pixar Animation Studios produce Toy Story, the first computer-animated full-length feature film

NOTE : OpenGL (Open Graphics Library) is a cross-language, cross-platform application programming interface (API) for rendering 2D and 3D vector graphics. The API is typically used to interact with a graphics processing unit (GPU), to achieve hardware-accelerated rendering.

2000s

- GPUs become programmable
- Large leaps in real-time graphics
- Movie industry rules graphics, drives research
- More realistic rendering, faster
- Physical simulation
- Motion capture

Data center GPUs can offer better support for parallel operations, AI, media, media analytics, and 3D rendering solutions. Example **Gaming, Machine learning, High performance computing, Creative production**

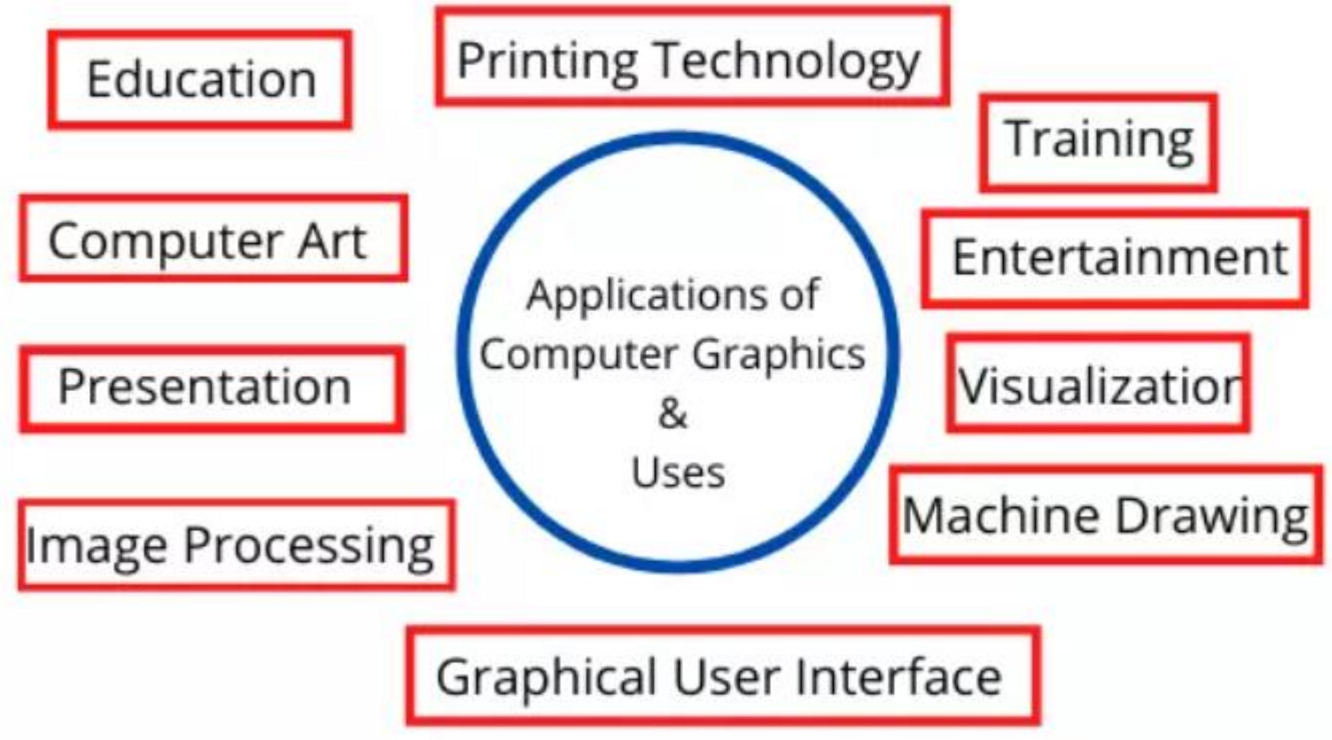
Related Studies

- Connected studies include:
  - Image processing
  - Computer vision
  - Information visualization
  - Scientific visualization
  - Applied mathematics
  - Computational geometry
  - Computational topology

Computer Graphics vs Image processing

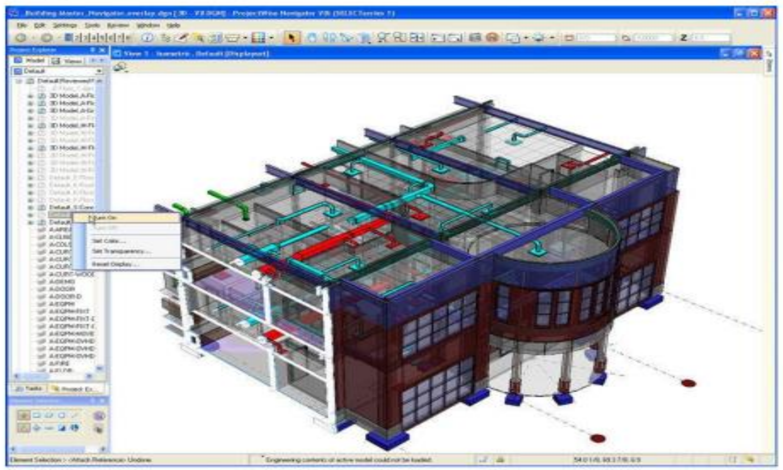
- **Computer graphics**
  - Computer graphics involves in generating images from mathematical or geometrical models
  - It includes the creation, storage and manipulation of images or objects
  - E.g. Drawing a picture
- **Image processing**
  - Image processing involves in analysing the images to derive mathematical or Geometrical models
  - It is the part of computer graphics that handles image manipulation or interpretation.
  - E.g. Making blur image visible

Application



Computer aided Design

- Computer-aided design (CAD) is the use of computer technology for the design of objects, real or virtual
- 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
- These designs are more frequently used to test the structural, electrical, and thermal properties of the systems



Digital Art/ Computer Art

- 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
- Illustrator, coral draw, Photoshop, adobe muse and other different types of applications for creating new designs
- The impact of digital technology has transformed traditional activities such as painting, drawing and sculpture, while new forms, such as net art, digital installation art, and virtual reality, have been recognized artistic practices

Entertainment and Gaming

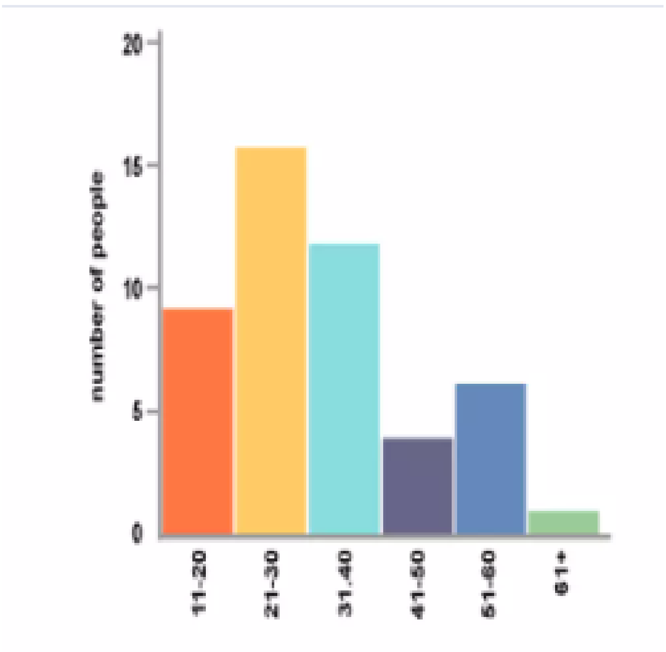
- Computer graphics methods are new commonly used in making motion pictures, music videos and TV shows
- Images are drawn in wire-frame form and will be shaded with rendering methods to produce solid surfaces
- Music videos use graphics in several ways

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
- Training with computer-generated models of specialized systems such as the training of ship captains and aircraft pilots
- A student can learn surgery using data gloves and realistic computer graphics

Presentation Graphics

- It is used to produce illustrations for reports or to generate 35-mm slides for use with projectors
- Examples of presentation graphics are bar charts, line graphs, surface graphs, pie charts and displays showing relationships between parameters
- 3-D graphics can provide more attraction to the presentation



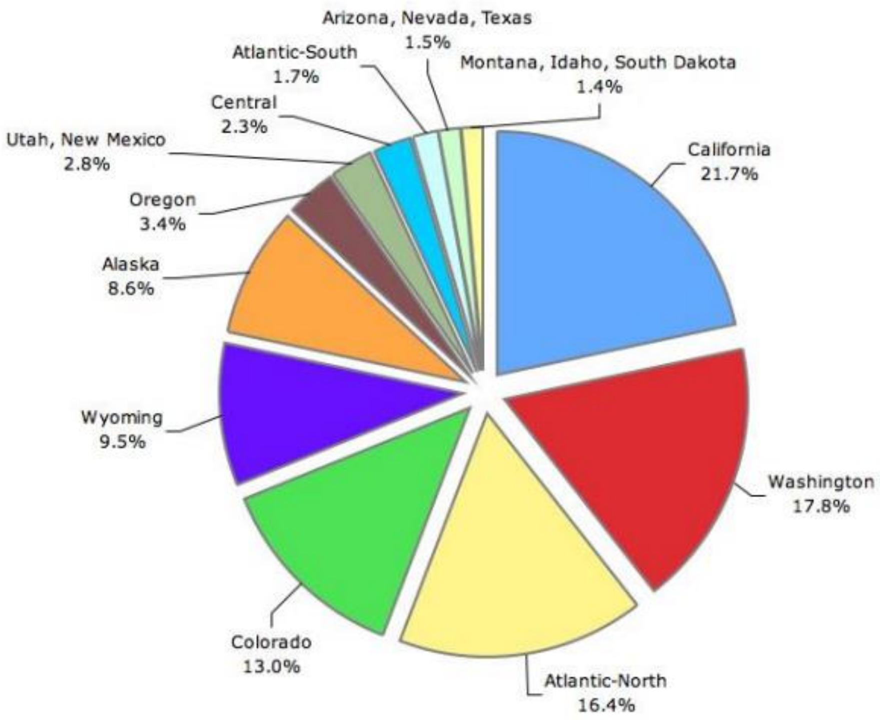


Image Processing

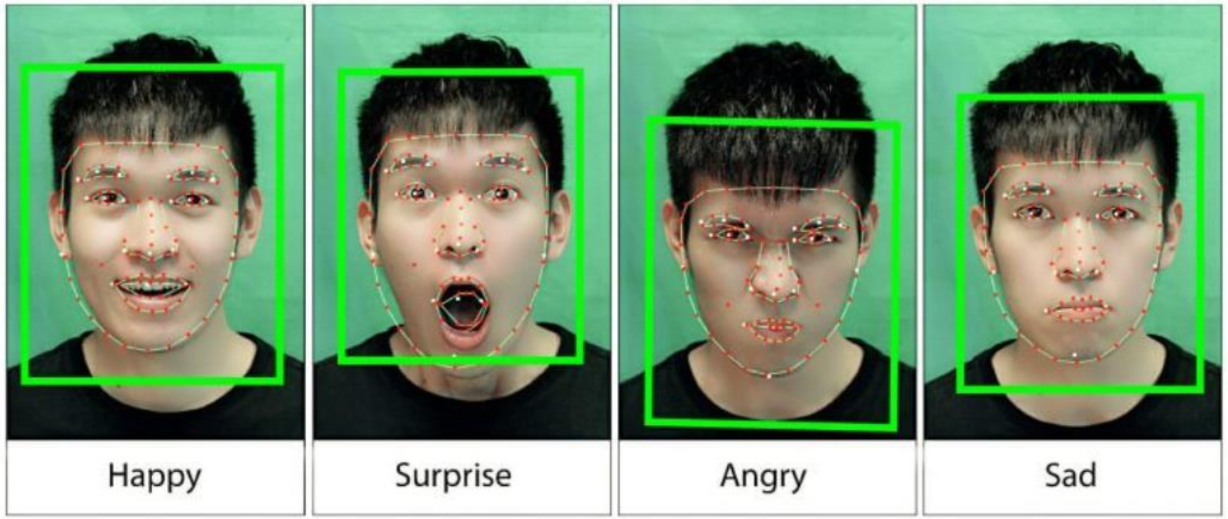
- Image processing is to apply techniques to modify or interpret existing pictures. It is widely used in medical applications

- Image can be created using simple point program or can be fed into computer by scanning the image

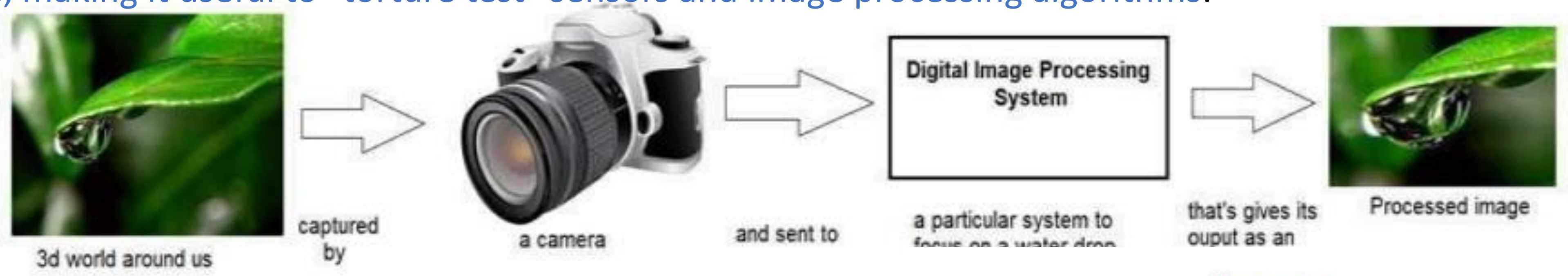
- These picture/ images need to be changed to improve the quality

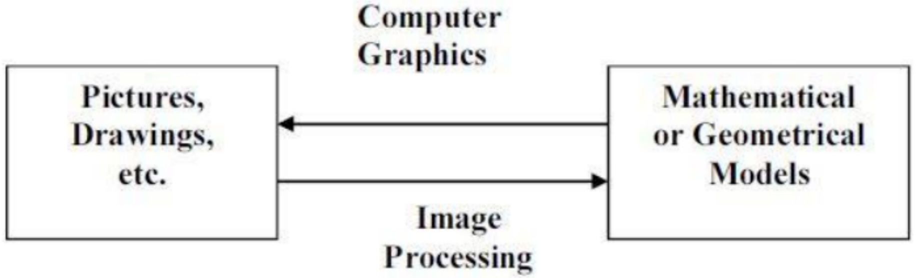
- image/pattern recognition systems, images need to be changed in specified format so that the system can recognize the meaning of the picture

- Currently computer graphics is widely used for image processing



Lenna: This image does contain a wide range of spatial frequencies as well as intensity range, making it useful to "torture test" sensors and image processing algorithms.





Graphical User Interface (GUI)

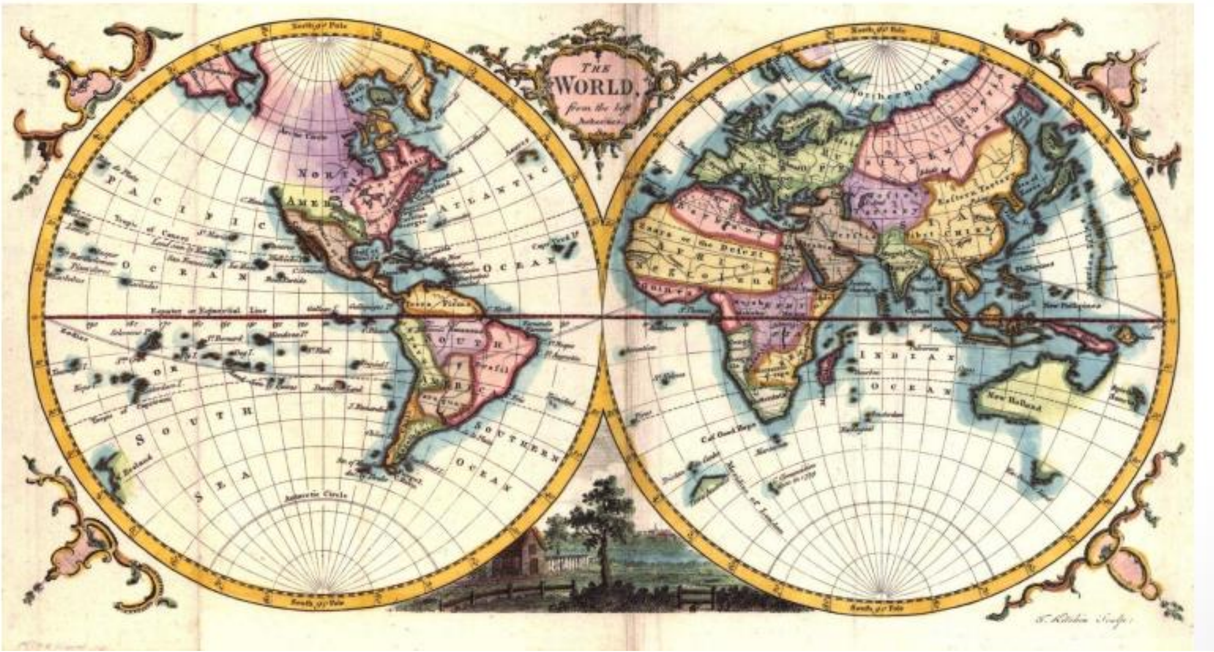
- GUIs have become key factors for the success of the software or operating system
- GUI provides point-and-click facilities to allow users to select menu items, icons, and objects on the screen
- Word processing, spreadsheet, and desktop-publishing programs are typical applications that take advantage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

Visualization

- The numerical and scientific data are converted to a visual form for analysis and to study the behaviour called visualization
- Converting data to visual form can help to understand mass volume of data very efficiently
- Producing graphical representation for scientific data sets are called scientific visualization
- Business visualization is used to represent the data sets related to commerce and industry
- The visualization can be either 2D or 3D
- The weather department also uses visualization to obtain weather information. So that the information about the data of a field can be studied properly.

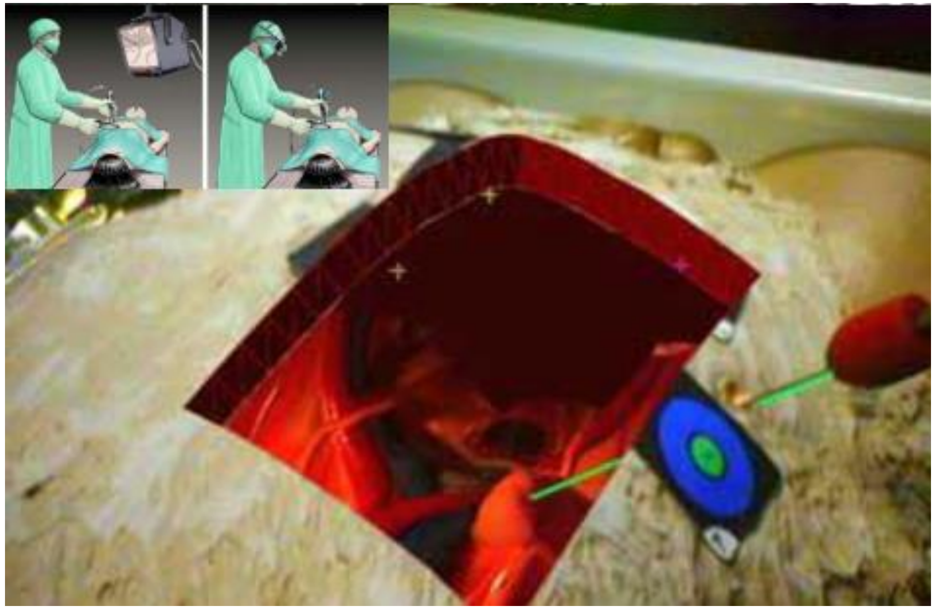
Cartography

- 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.



Simulation

- A representation of a problem, situation, etc. in mathematical terms, using a computer is called simulation
- Simulation is the imitation of the conditions like those, which is encountered in real life
- Simulation thus helps to learn or to feel the conditions one might have to face in near future without being in danger at the beginning of the course
- Recently computer graphics is widely used to create simulated environment
- E.g. Robot Operation Simulation, Pilot Training, Military Training etc.



Virtual Reality (VR) and Augmented Reality (AR):

- **Virtual Reality (VR) and Augmented Reality (AR)**: Computer graphics has enabled the development of *VR and AR applications* that extend beyond gaming. In the realm of education, VR can transport students to historical events or allow them to explore the human body in 3D. In the field of engineering, AR glasses can overlay critical information on physical machinery, making *maintenance tasks* more efficient and reducing errors.

VS

AUGMENTED REALITY

- Overlays computer generated 3D content on the real world
- User is able to interact with real world and virtual world
- User can clearly distinguish between both the worlds.
- It is achieved by smartphones, tablets or AR wearables.

VIRTUAL REALITY

- Visually immerse the user with simulated objects and environment.
- Completely shut down the real world and make user think that they are really in the virtual world.
- User finds it hard to differentiate between virtual and real world.
- It is achieved by VR headsets.

Application in Medical Field

Virtual and Augmented Reality in Medical Imaging

- VR and AR are digital technologies that allow automation and can be used in fields where repetitive tasks need to be performed and often perfected .

- A common example for the use of VR and AR in the medical field is medical education and training, especially in surgery. For example, using VR or AR in surgical procedure training allows the trainee to perform steps on a virtual patient or having patient information superimposed with reality.

- There is some evidence that VR could be a useful tool in improving surgical skills and reducing surgical procedure errors . Neurosurgery, representing a traditionally complex surgical area, has been positively affected by the development of virtual techniques.

Image processing and AI in medical field

- Medical imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) play a pivotal role in providing clinicians with detailed and comprehensive visual information about the human body.
- These imaging modalities generate vast amounts of data that require efficient analysis and interpretation, and this is where AI steps in.
- AI, particularly deep learning algorithms, has demonstrated remarkable capabilities in extracting valuable insights from medical images . Machine Learning, Deep learning models, trained on large datasets, are capable of recognizing complex patterns and features that may not be readily discernible to the human eye .
- These algorithms can even provide a new perspective about what image features should be valued to support decisions . One of the key advantages of AI in medical imaging is its ability to enhance the accuracy and efficiency of disease diagnosis.
- Through this process, AI can assist healthcare professionals in detecting abnormalities, identifying specific structures, and predicting disease outcomes


medical
infographic
AI

- By leveraging machine learning algorithms, AI systems can analyze medical images with speed and precision, aiding in the identification of early-stage diseases that may be difficult to detect through traditional methods.

- This early detection is crucial as it can lead to timely interventions, potentially saving lives and improving treatment outcomes .

- Furthermore, AI has opened up new possibilities in image segmentation and quantification. By employing sophisticated algorithms, AI can accurately delineate structures of interest within medical images, such as tumors, blood vessels, or cells.

- This segmentation capability is invaluable in treatment planning, as it enables clinicians to precisely target areas for intervention, optimize surgical procedures, and deliver targeted therapies

Computer vision

- Computer vision is a scientific field which deals with how computers can be made as high level devices which understand digital images and videos. In terms of engineering, it is an automate task that the human visual system can do.
- Computer vision has methods for acquiring, processing, analyzing and understanding the digital image. The most important task is to extract high dimensional data from the real world which can produce numerical or symbolic information.
- As a scientific discipline, computer vision is related to the theory of artificial system which can extract information from images. The image data is used in the form of video sequences which can be seen by a human.

Applications of Computer vision is as follows:

- Robotics
- Medicine
- Security
- **Transportation (E.g.. Traffic Flow Analysis, License plate recognition, Vehicle Classification, Driver Monitoring)**
- Industrial Automation

Types of computer Graphics

- Computer **graphics types**:
  - **Interactive Computer Graphics**
  - **Non-interactive Computer Graphics**

Interactive Computer Graphics

❑Involves two way communication between computer and user.

❑User has full control over the content

❑In the Interactive Graphics, data / information shown in the display unit can be interact by one or more input device

❑I/O Device request to system/ computer then O/P as a graphical content

❑Example: Simulator, User Interface, ping pong game etc.

Non-interactive Computer Graphics

- Involves one-way communication between user and computer /system
- User has control over some parts of the contents and totally controlled by program
- Basically, user can see the produced image and cannot make any changes

- Also called **passive computer graphics**
- Example: Videos, Images etc.

Hardware and Software for CG

- ❑Hardware are the physical elements of the computer
- ❑Hardware can be classified as
  - **Input Devices**
  - **Output Devices**
- ❑Input Devices are
  - Keyboard
  - Mouse
  - Joy Stick
  - Light Pen
  - Scanner
  - Optical Character Reader
  - Bar Code Reader

- Output Devices are
  - Cathode Ray Tube (CRT)
  - Flat Panel Display
    - Liquid Crystal Display (LCD)
    - Light Emitting Diode (LED)

CG Terminologies

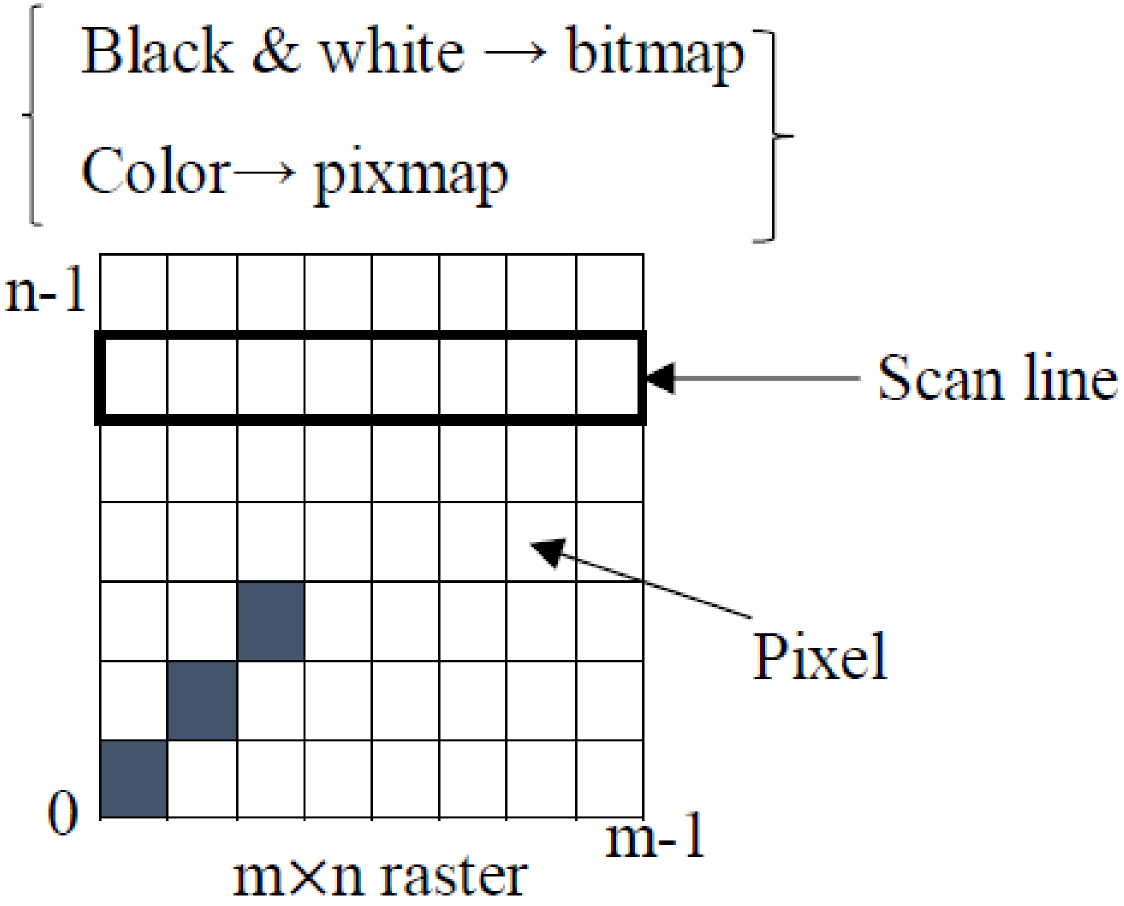
Pixel

- It is the fundamental building block of any image of graphics
- Also called picture elements
- It is the addressable smallest screen element
- Each pixel has its own intensity, name and address by which it can be identified among several pixels
- For many very high-resolution displays, they become essentially invisible
- At a given time, each pixel can show only one colour
- **Scan line*:*** A row of pixel

- **Bitmap**
  - It is a ones and zeros representation of the rectangular array of points on the screen
  - Each point is called a pixel
  - In their simplest form, bitmaps have only two colors, with each pixel being either black or white
  - Single pixel-single bit-2 colors

- **Pixel Map**
  - An image of more than two colors
  - Single pixel-multiple bits- ($2^{n)}$ multiple colors

CG Terminologies



Resolution

- It is defined as the total number of pixel in our display screen

Resolution= No. of pixel in X-direction * No. of pixel in Y-direction

  - 800*600 means
  - Resolution =480000 pixels

Aspect Ratio

- It is defined as the ratio of total number of pixel in X-direction to the total number of pixel in Y direction

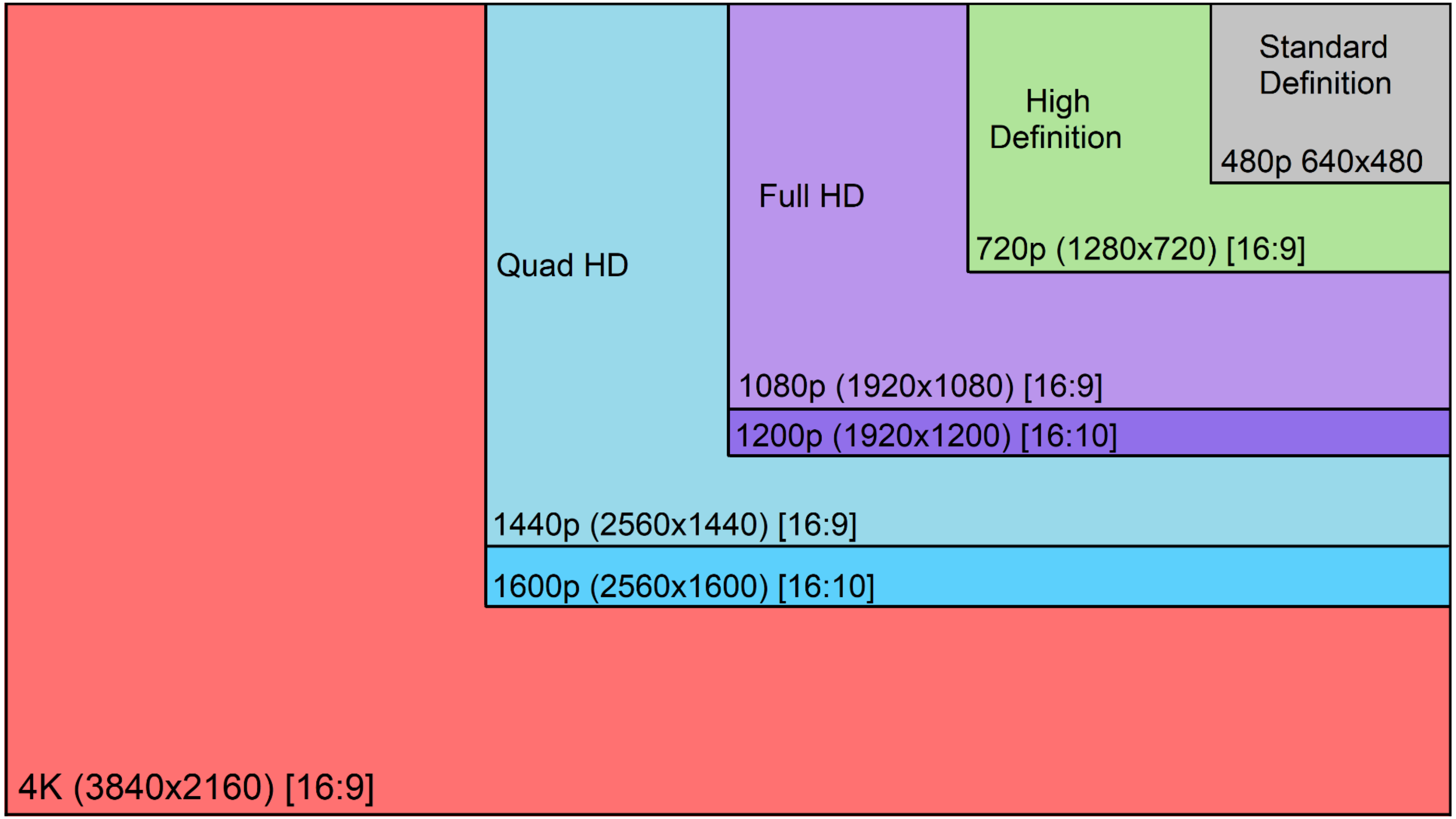
Aspect Ratio = No. of pixel in X-direction / No. of pixel in Y-direction

Example

800*600 means, Resolution = 480000 pixels

Aspect Ratio= 4:3

CG Terminologies



Bit depth/color depth

- Bit depth is defined as the number of bits assigned to each pixel in an image (bpp or bits per pixel)

- The number of different colours in an image is depended on the depth of colour or bits per pixel

- For eg. 1 bit per pixel represents, 2^1 = 2 colours for each pixel, similarly 1 byte i.e. 8 bits represents 2^8 = 256 colours for each pixel

Frame Buffer/Refresh buffer

- It is the memory location where the intensity values of all pixels are internally stored
- It contains an internal representation of an image
- The screen is redrawn many times per second, so that almost immediately after the intensity values are changed in the frame buffer, the intensity of the pixels on the screen will be changed to match, and the displayed image will change
- Memory in **Mb** is given by
  - **x-resolution*y-resolution*bit per pixel / 8*1024*1024**

- A pixel in a frame buffer may be represented by one bit as in monochromatic system where each pixel on CRT screen is either on ‘1’ or off ‘0’ having 640 x 480 pixels will thus require (640 x 480 x 24) / 8 = 9kb of RAM

- It may be represented by eight bits resulting 2^8 = 256 gray levels for continuous shades of gray on CRT screen

- In colour system each of the three colour red, green and blue is represented by eight bits producing 2^{24} = 16 million colours

- A medium resolution colour display having 640 x 480 pixels will thus require (640 x 480 x 24) / 8 = 9kb of RAM

Refresh Rate

- Light emitted by phosphor fades very rapidly, so to keep the drawn picture glowing constantly; it is required to redraw the picture repeatedly and quickly directing the electron beam back over the some point

- The no of times/sec the image is redrawn to give a feeling of non-flickering pictures is called refresh-rate

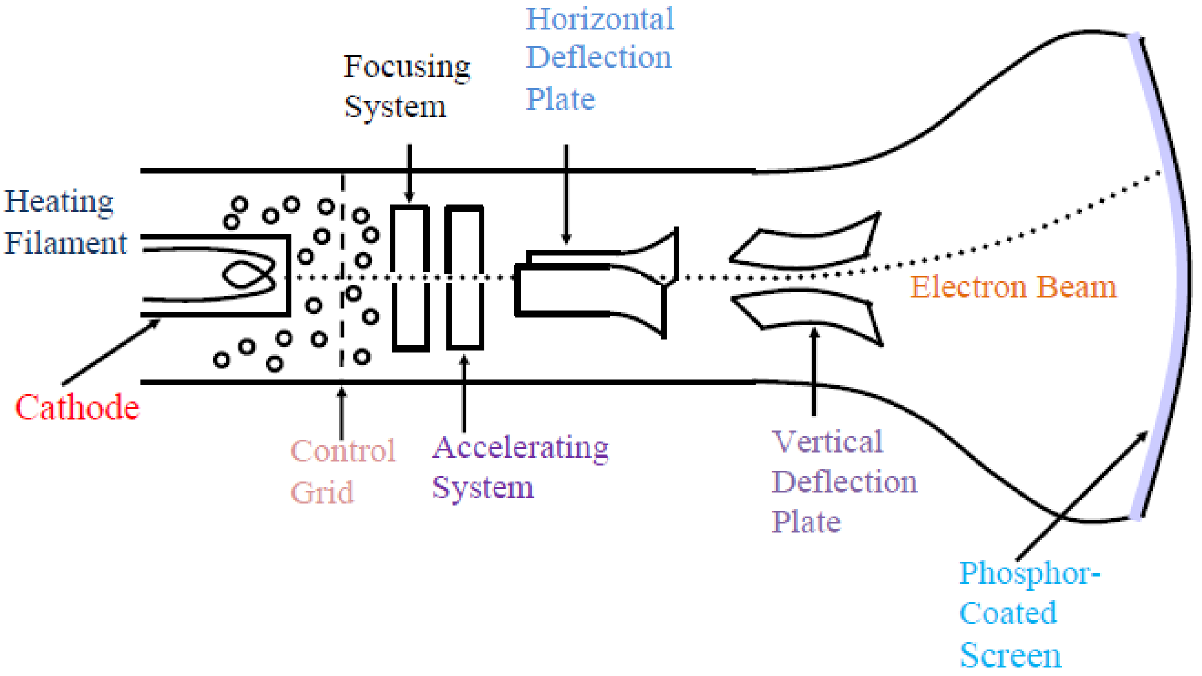
- If refresh rate decreases, **flicker** develops

- Refresh rate above which flickering stops and steady it may be called as **critical fusion frequency (CFF)**

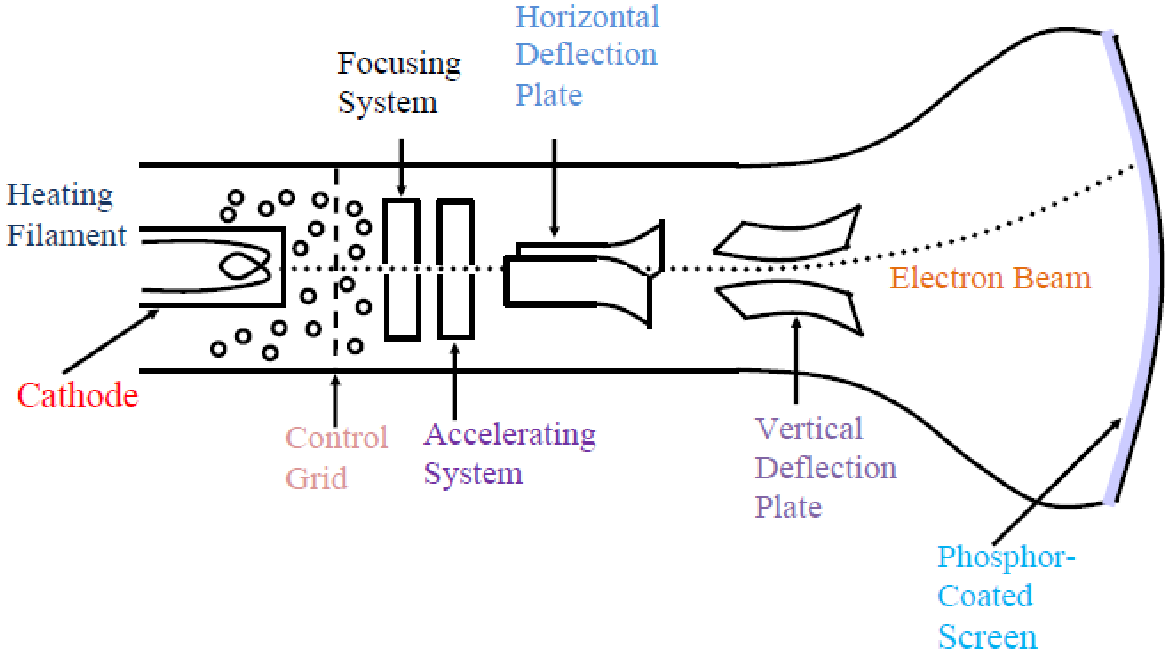
- Normally 60 to 80 hz

Hardware Concepts

- The display devices used in graphics system is video monitor. The most common video monitor is based on CRT technology
- **Cathode Ray Tube (CRT)**



- Components:
  - **Electron Gun**: composed of heated metal cathode and control grid
  - **Accelerating Anode**
  - **Focusing System**
  - **Deflection system**
  - **Phosphor Screen**



- A CRT is an evacuated glass tube, with a heating element on one end and phosphor-coated screen on the other end

- When current flows through heating filament, the electrons are piled upon the filament. These electrons are attracted by accelerating systems on the phosphor coated screen

- When electron strikes on the screen, the phosphor emits a small spot of light at each position contacted by the electron beam

- The glowing positions are used to represent the picture in the screen

- The negative voltage applied at cylindrical control grid controls the intensity of electron beam by repelling electrons
  - High negative voltage stops electron passing from the hole of control grid while small negative voltage decreases electron passage

- 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

Phosphorescence

- It is a process in which energy absorbed by a substance is released slowly in the form of light.

Persistence

- How long a phosphor continues to emit light after the electron beam is removed?
- Persistence of phosphor is defined as **time** it takes for emitted light to decay to 1/10 (10%) of its original intensity
- Range of persistence of different phosphors can react many seconds
- The phosphor used for graphics display device usually have persistence of 10 to 60 microsecond
- A phosphor with lower persistence is useful for animation and a higher– persistence phosphor is useful for displaying highly complex static picture

Classwork

- ***There is a system with 24 bits per pixel and resolution of 1024 by 1024. Calculate the size of frame buffer.***

Q1. There is a system with 24 bits per pixel and resolution of 1024 by 1024. Calculate the size of frame buffer.

- ***Solution:***

Resolution = 1024 × 1024

Total number of pixel = 1024*1024 = 1048576 pixels

Per pixel storage = 24 bits

Total storage required in frame buffer = 1048576*24 = 25165824 bits

= 25165824/8 byte

= 25165824/(8*1024) kb

= 25165824/(8*1024*1024)Mb

= 3 Mb

Classwork

- ***Consider a RGB raster system is to be designed using 8 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 8 bits per pixel in the frame buffer, how much storage do we need for the frame buffer?***

Classwork

- Q2. Consider a RGB raster system is to be designed using 8 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 8 bits per pixel in the frame buffer, how much storage do we need for the frame buffer?

Solution:

Size of screen = 8 inch × 10 inch

Pixel per inch = 100

Total no. of pixel = (8*100)*(10*100) = 800000 pixels

Per pixel storage = 8 bit

Total storage required in frame buffer = 800000*8 bits = 6400000 bits

= 6400000/8 bytes = 800000 byte

Display Technologies

1. Most of the display make use of **CRT’s** in past
2. Recent **Flat Display**, due to their low power consumption and thinner designs

Types of **CRT display** technology are:

- **Raster-Scan Display**
- **Random-Scan Display**

Raster/refresh Scan display

- This technology based on television technology was developed in early 70s
- Raster consists of a pixels organized into rows and columns (grid)
- In this display, raster points are used as basic drawing primitive
- In raster scan system, the electron beam is **swept across the screen**, one row at a time from top to bottom
- As electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots
- Home television and printers are example of system using raster scan method

- Picture definition is stored in memory called **frame buffer** or **refresh buffer**
- Frame buffer holds the set of intensity values for all the screen points
- Stored intensity values are then retrieved from the frame buffer and painted on the screen one row(**scan line**) at a time

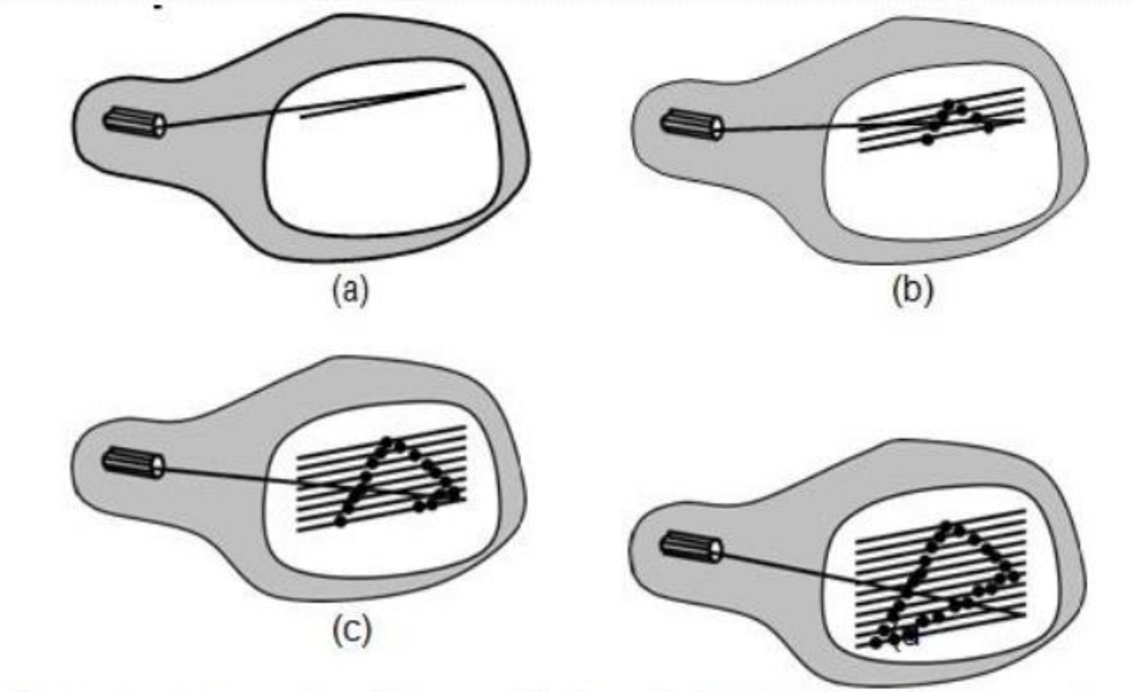
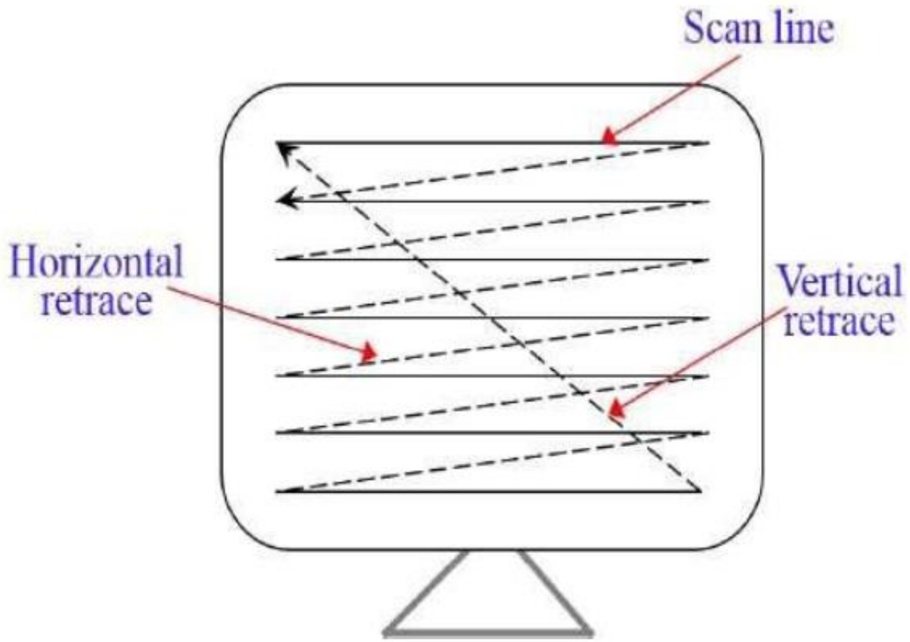


Figure: A raster-scan system displays an object as a set of points across each screen scan line

- The number of scan lines per second is called **horizontal scan rate**

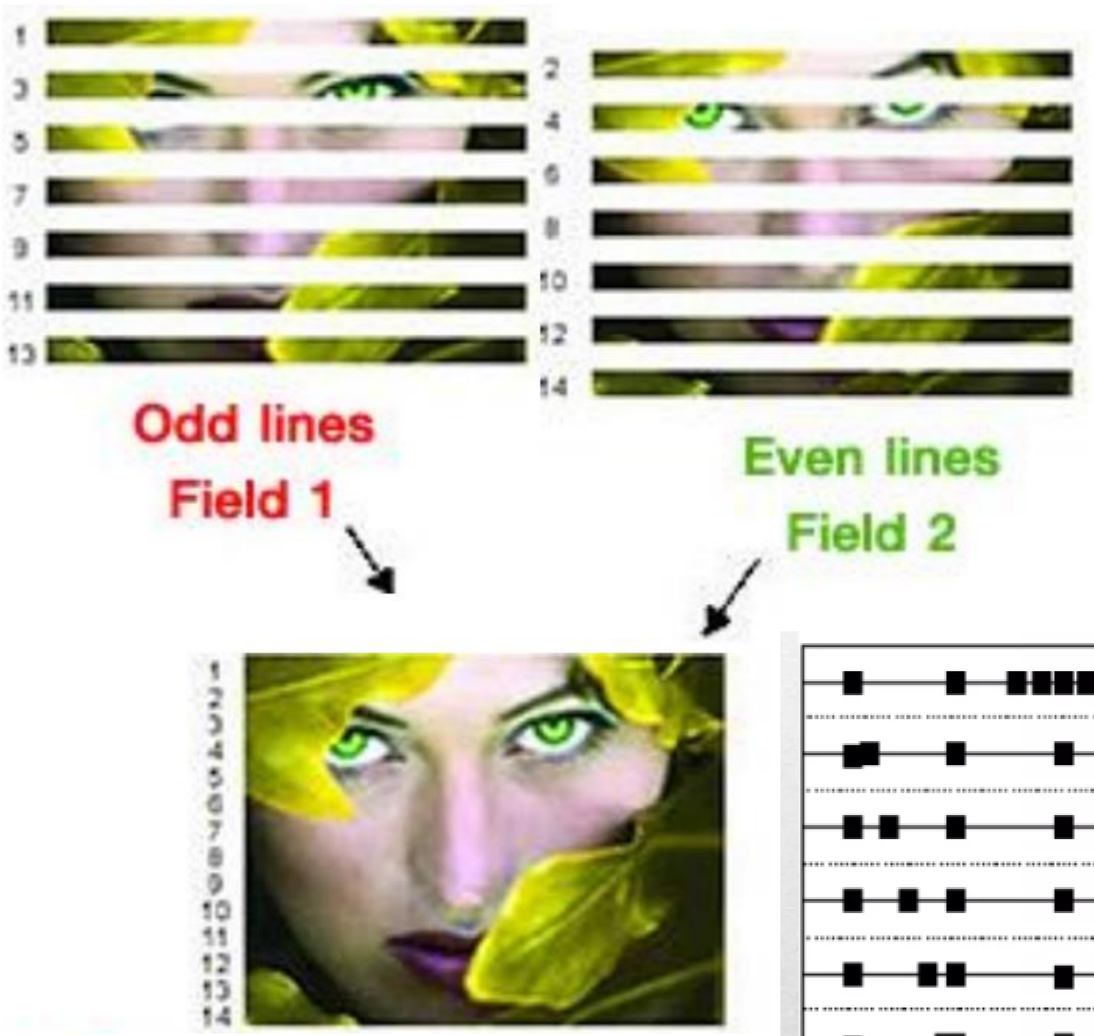
- Returning of electron beam from right end to left end after refreshing each scan line is called **horizontal retrace**

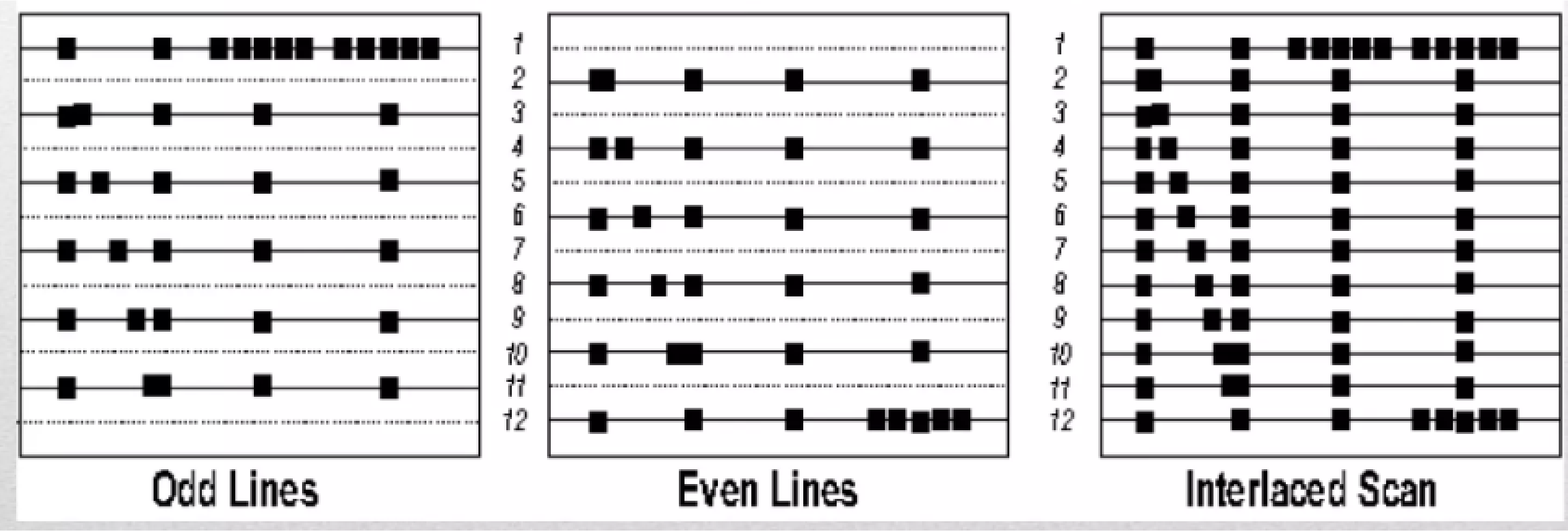
- At the end of each frame, the electron beam returns to the top left corner to begin next frame called **vertical retrace**



Raster Scan display …

- **Interlaced vs. non-interlaced scan** (refresh procedure)
  - When referring to a computer monitor or another display, interlace or interlacing is a description of how the picture is created
- In **non-interlaced** refresh procedure, electron beam sweeps over entire scan lines in a frame from top to bottom in one pass
- In **interlaced scan**, each frame is displayed in two passes:
  - First pass for odd scan lines and another for even ones
  - This allows to see the entire screen displayed in one-half the time it would have taken
  - Interlacing is primarily used with slower refreshing rates. This is an effective technique for avoiding screen flickering provided adjacent scan line contains similar information


Odd lines
Field 1
Even lines
Field 2


Odd Lines
Even Lines
Interlaced Scan

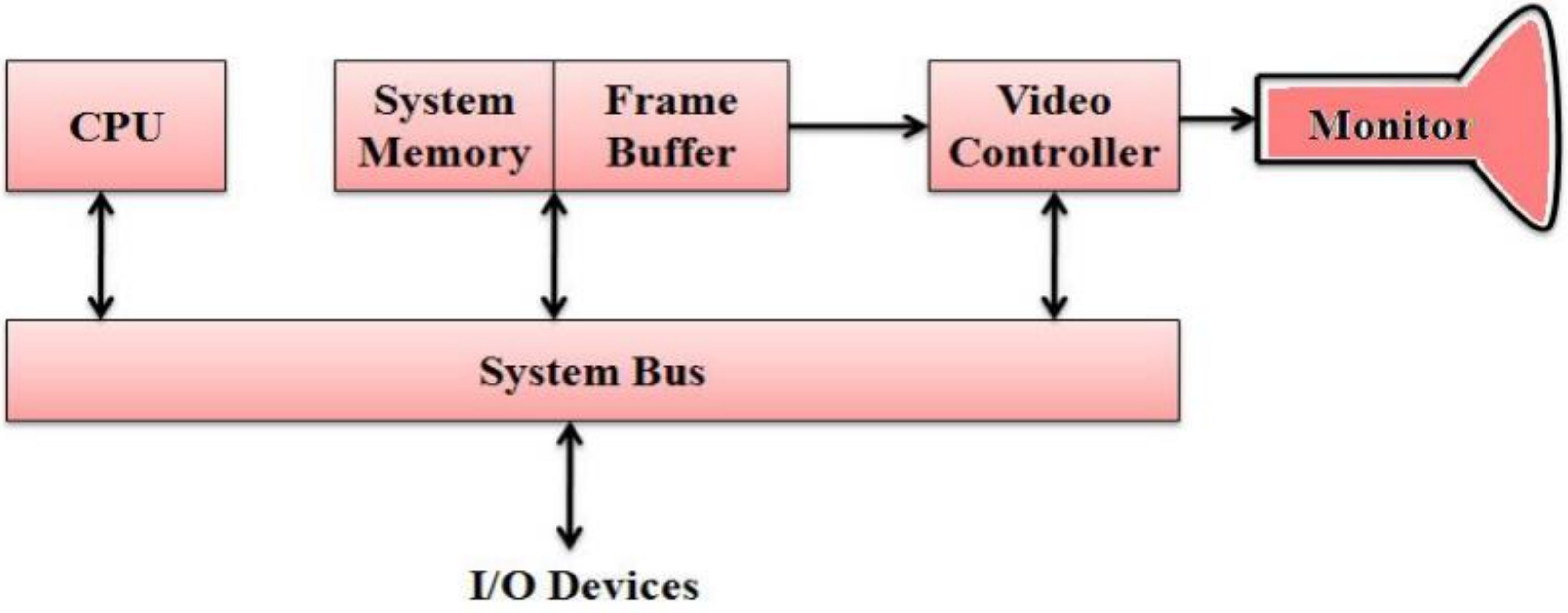
ADVANTAGES:

- Rendering of sharp and clear images with fine details, making it suitable for applications requiring high-quality graphics
- Realistic images with different shades can be displayed
- Wide range of color available

DISADVANTAGES:

- Resolution is lower than random scan display
- May exhibit pixilation or aliasing effect
- More memory is required as data about the intensities of all pixel has to be stored

Architecture of Raster-Scan System



- It consists of central processing unit, a video controller, a monitor, system memory and peripheral devices such as mouse and keyboard

- A fixed area of system memory is reserved for frame buffer

- CPU is the main processing unit of computer systems

- Besides CPU, it consists of a special purpose processor called **video controller** or **display controller**

Video controller

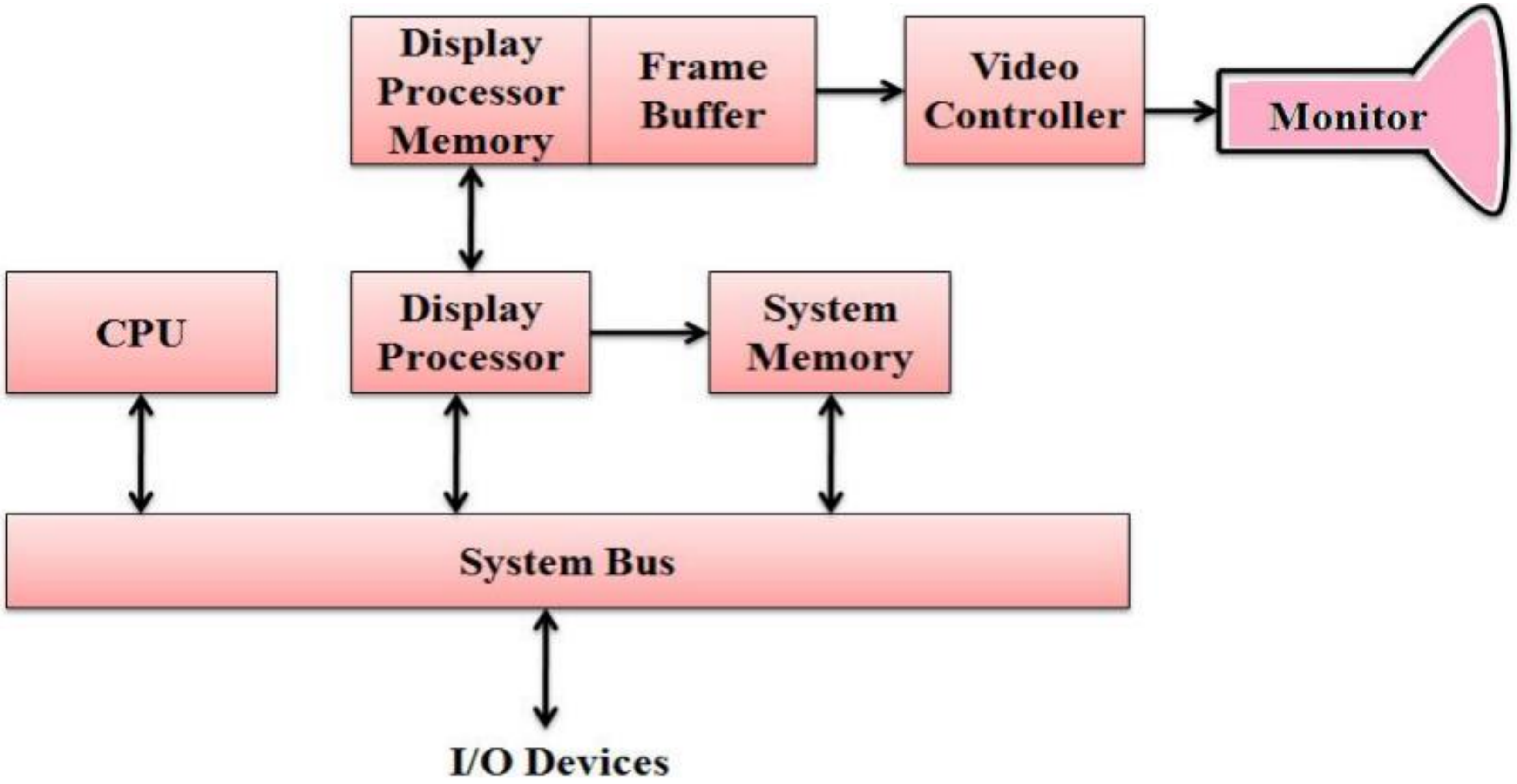
- It controls the operation of the display device
- It has the direct access to the frame buffer for refreshing the screen
- It cycles through the frame buffer, one scan line at a time typically 50 times per second or higher
- It brings a value of each pixel contained in the frame buffer and uses it to control the intensity of the CRT electron beam

- Frame-buffer locations, and the corresponding screen positions, are referenced in Cartesian coordinates

- The contents of the frame buffer at the specific pixel position(x,y) are retrieved and used to set the intensity of the CRT beam

- There exists a one to one relationship between the pixel in the frame buffer and that on the CRT screen

- After cycling through all pixels along the bottom scan line, the video controller resets the registers to the first pixel position on the top scan line and the refresh process starts over



Architecture of a raster-graphics system with a display processor

Display processor (graphics controller, display coprocessor)

- To free the CPU from the graphics chores

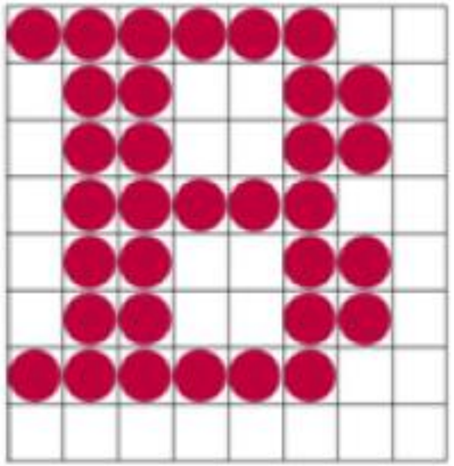
- In addition to system memory, separate display processor memory is also provided

- Major task is to digitize a picture definition given in a application program into a set of pixel intensity values to store in frame buffer. This process is called scan conversion
  - For line, pixel position closest to the line path is located and store the intensity for each position in the frame buffer

- Display processors are also designed to perform a number of additional operations

- These functions include generating various line styles (dashed, dotted, or solid), displaying color areas, and applying transformations to the objects in a scene.

- Also, display processors are typically designed to interface with interactive input devices, such as a mouse



Random-Scan (Vector) Display

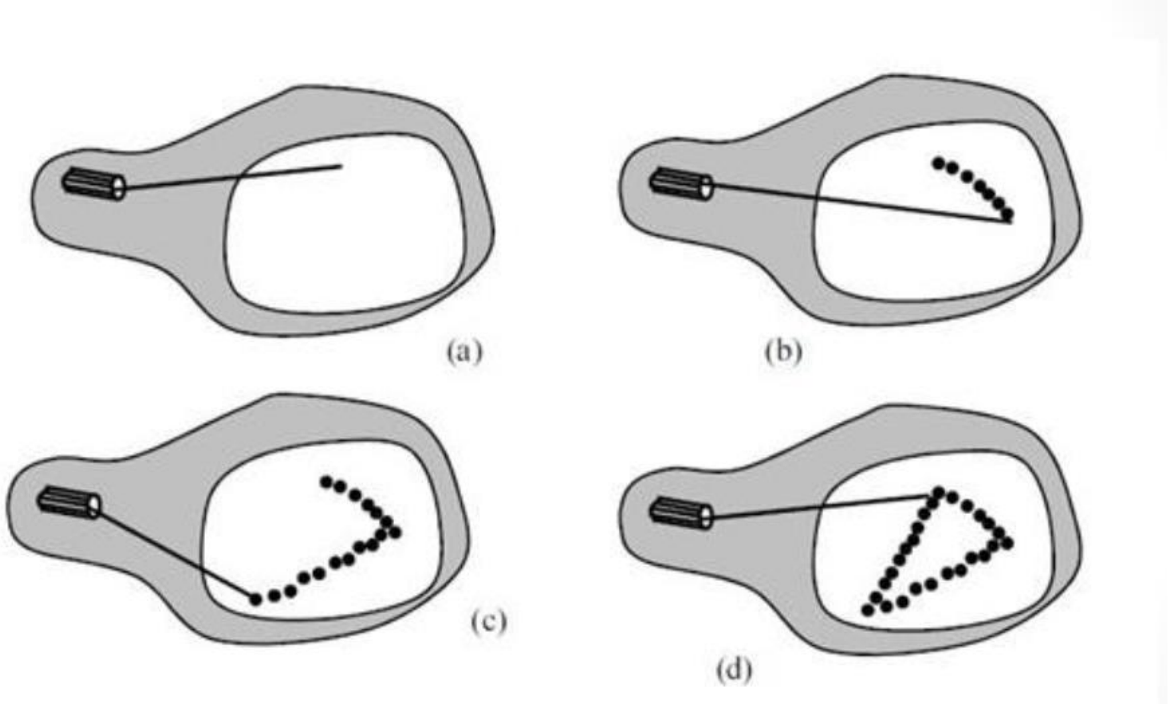
- In a **random scan** display unit, electron beam directed towards only to the parts of the screen where a picture is to be drawn

- Random-scan monitors draw a picture one line at a time and for this reason are also referred to as **vector displays** (or **stroke-writing** or **calligraphic** displays)

- Random scan system uses an electron beam which operates like a pencil to create a line image on the CRT

- The component line can be drawn or refreshed by a random scan display system in any specified order

- Pen plotter is a random scan hard copy device



The number of lines regulates refresh rate on random-scan displays

An area of memory called **refresh display files** stores picture definition as a set of line drawing commands

Refresh display files also called **display list**, **display program** or **refresh buffer**

- The system returns back to first-line command in the list, after all the drawing commands have been processed

- Random scan displays are designed to draw all the components line of a picture 30 to 60 times each second

- High-quality vector systems can handle around 100,000 short lines at this refresh rate

- Higher resolution than raster system as the picture definition is stored as the set of line drawing instructions and not a set of intensity values

- Vector displays produce smooth line drawings because the CRT beam directly follows the line path

Advantages:

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

Disadvantages:

- A vector display can not fill areas with patterns and manipulate bits
- Time required for refreshing an image depends upon its complexity (more the lines, longer the time) the flicker may therefore appear as the complexity of the image increases

- The fastest vector display can draw about 100000 short vectors in a refresh cycle without flickering

Architecture of Random-Scan System

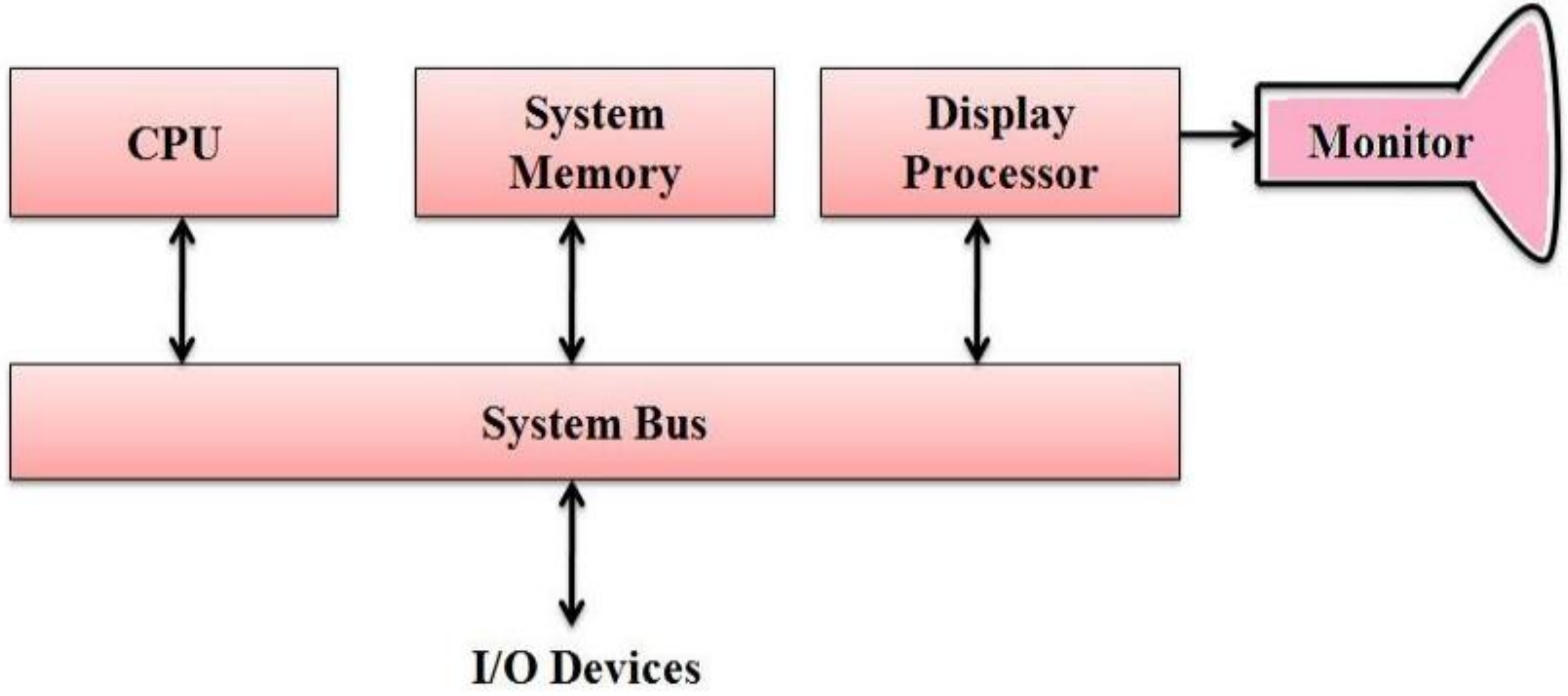


FIG : Architecture of Vector Display System

Architecture of Random-Scan System

- It consists of a CPU, a **display processor** , a monitor, system memory and peripheral devices such as mouse and key board

- The display processor is also called as **display processing unit** or **graphics controller**

- The **application program** and **graphics package** both reside in the system memory and execute on CPU

- Graphics commands in the application program are translated by the graphics package into a **display file/ display list** stored in the system memory

- This display file is then accessed by the display processor to refresh the screen

- The display processor cycles through each command in the display file program once during every refresh cycle

- Display processor helps to converts the digital coordinate values to analog voltages for circuits that displace an electron beam hitting on the CRT’s phosphor coating

Raster and Vector Graphics

- **Raster Graphics**

  - A raster image is made up of pixels, each a different colour, arranged to display an image
  - Raster image pixels do not keep on their appearance as size increases- when you zoom in a photograph, it becomes blurry for this reason
  - The most common raster file types include JPG, GIF, PNG, TIF, BMP, and PSD

- **Vector Graphics**

  - A vector image is made up of paths, each with a mathematical formula (vector), that tells the path how it is shaped and what colour it is bordered with or filled by
  - Vector images keep on appearance regardless of size, since the mathematical formulas dictate how the image is rendered
  - The most common vector file types are AI(Adobe Illustrator[logo]), CDR(Corel DRAW) , and SVG(scalable vector graphic)

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

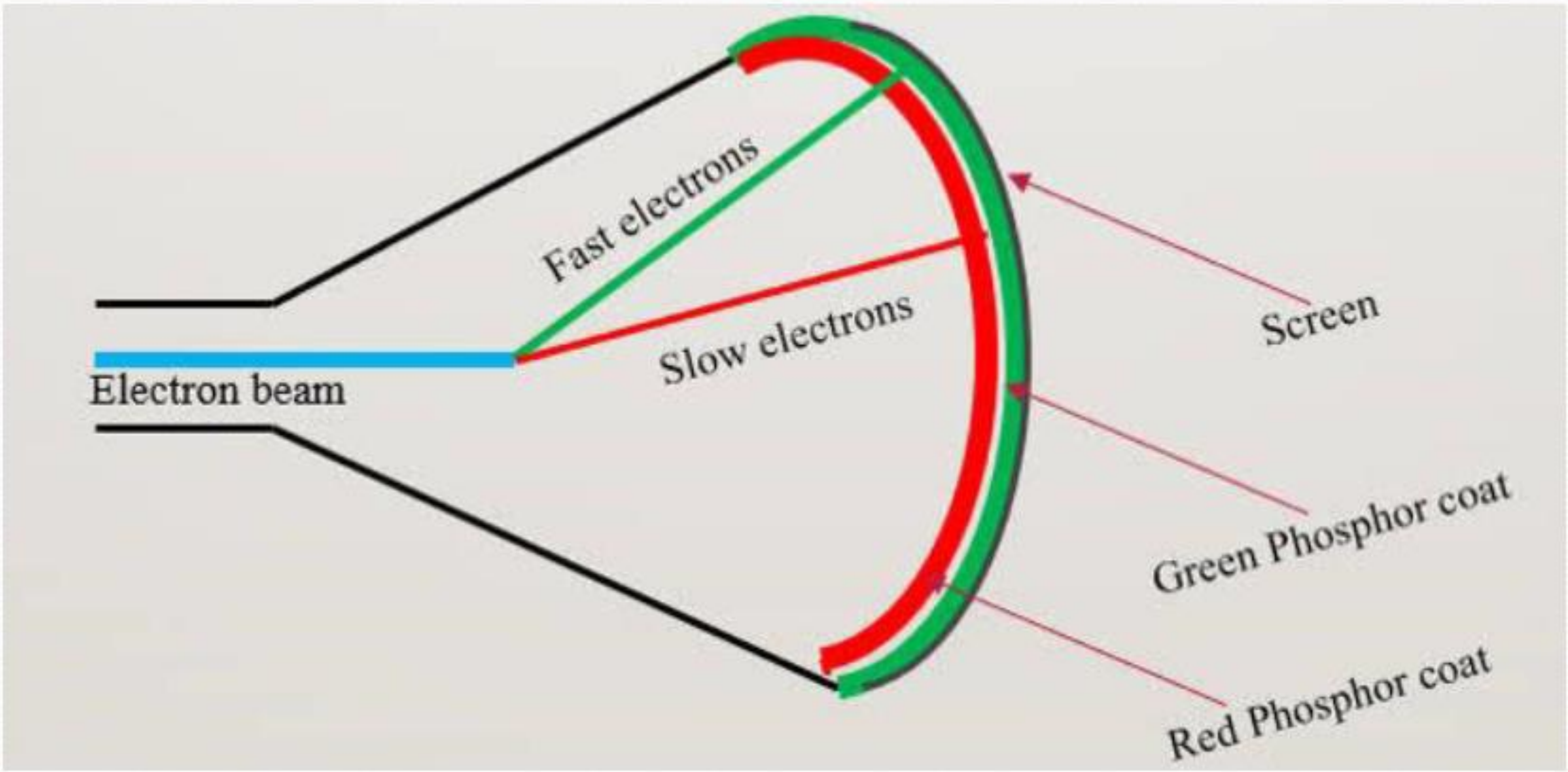
Color CRT

- Color depends on the light emitted by phosphor
- By combining the emitted light from the different phosphors, a range of colors can be generated
- Chemical composition of most important CRT TV phosphors
  - Red Phosphor $Y_2O_2S:Eu$
  - Green Phosphor ZnS:Cu,Al,Au
  - Blue Phosphor ZnS:Ag
- The two basic techniques for producing color displays with a CRT are:
  1. **Beam Penetration Method**
  2. **Shadow Mask Method**

Beam Penetration Method

- Used with random-scan monitors
- Two layers of phosphor: red and green
- The displayed color depends on how far the electron beam penetrates into the phosphor layers
- A beam of slow electrons excites only the outer red layer
- A beam of very fast electrons penetrates through the red layer and excites the inner green layer
- At intermediate beam speeds, combinations of red and green light are emitted to show two additional colors, orange and yellow

Beam Penetration Method



The speed of the electrons, and hence the screen color at any point, is controlled by the beam- acceleration voltage.

- **Advantage**
  - Economical way to produce colors
- **Limitations**:
  - Generation of only four colors is possible
  - Poor picture quality

Shadow Mask Method

- Shadow-mask methods are commonly used in raster-scan systems (including color TV)

- They produce a much wider range of colors than the beam-penetration method

- A shadow Mask CRT has **three phosphor color dots** at each pixel location

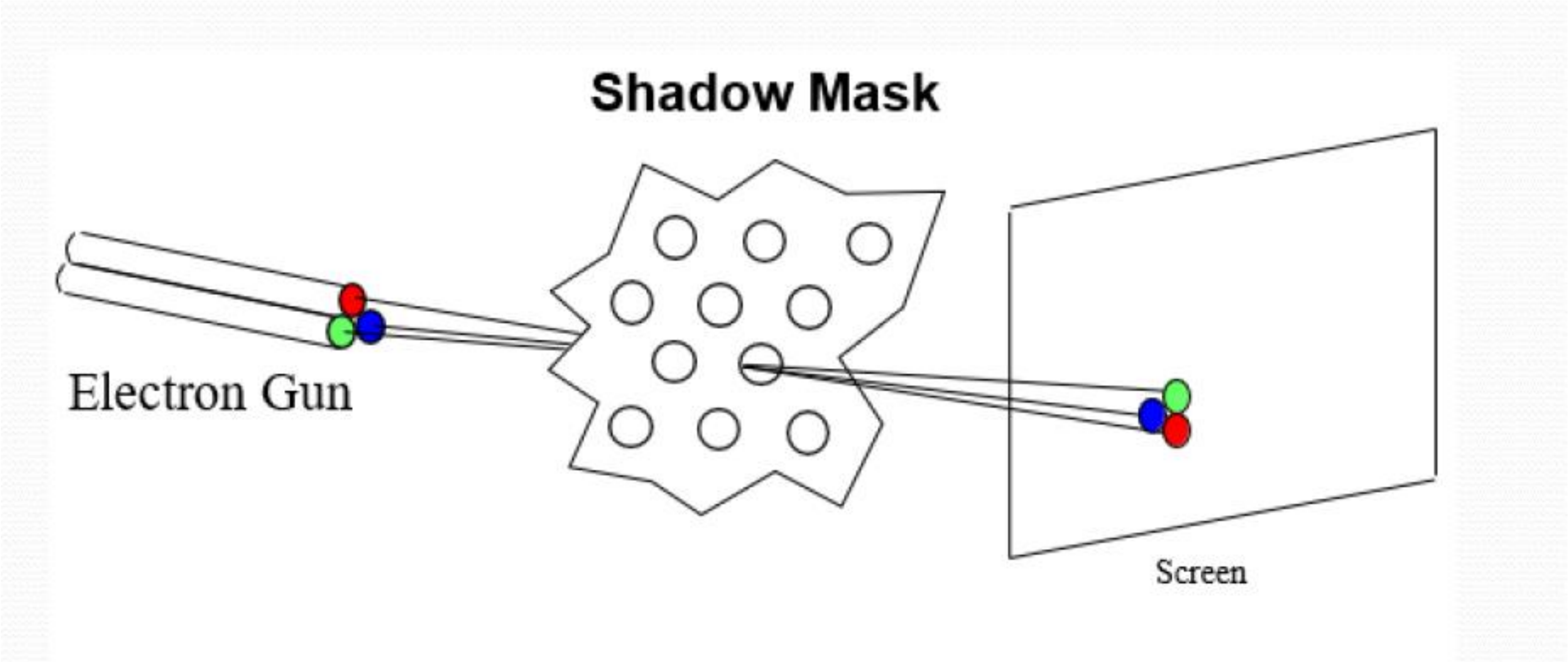
- One phosphor dot emits a red light, another emits green light and the last one emits a blue light

- This type of CRT also has **three electron guns** one for each color dot and a **shadow-mask grid** which is pierced with small round holes in a triangular pattern just behind the phosphor-coated screen

2 types of arrangements are possible

- **In-line method** and **delta delta method(Triad arrangement)**
- **Delta- Delta method**
  - Delta- Delta method is commonly used in color CRT system
  - A shadow mask is often used to ensure that the electron beams from the guns fall on the correct phosphors
  - The three electron beams are deflected and focused as a group onto the shadow mask

Shadow Mask Method



- When the three beams pass through a hole in the shadow mask, they activate a **dot triangle**, which appears as a small color spot on the screen

- The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask

- Color variations in a shadow-mask CRT are obtained by varying the intensity levels of the three electron beams

- The color of pixel is controlled by light intensity

- Different colors can be obtained by varying the intensity levels

- A white (or gray) area is the result of activating all three dots with equal intensity

- A black is produced with zero intensity of all colors

- Yellow=Red+ Green
- Magenta=Red+Blue
- Cyan= Blue +Green

- This produce 8 colors

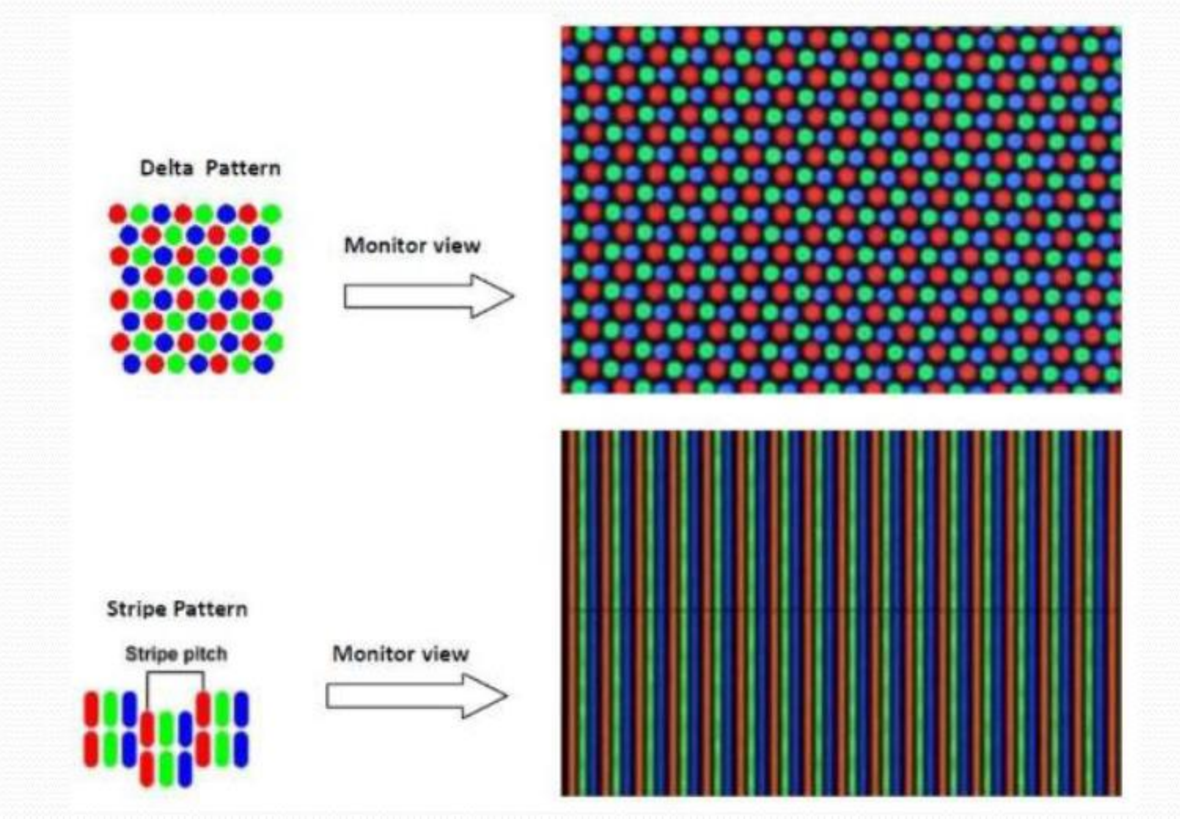
- **In-line method**

- 3 electron guns and the corresponding red - green-blue color dots on the screen, are aligned along one scan line rather of in a triangular pattern
- This inline arrangement of electron guns is easier to keep in alignment and is commonly used in high-resolution color CRT’s
- In some low-cost systems, the electron beam can only be set to on or off, limiting displays to eight colors
- More sophisticated systems can set intermediate intensity levels for the electron beams, allowing several million different colors to be generated

- Color CRTs in graphics systems are designed as RGB monitors

- These monitors use shadow mask method and take the intensity level for each gun

- A RGB color system with 24 bits of storage per pixel is known as **full color system or true color system**

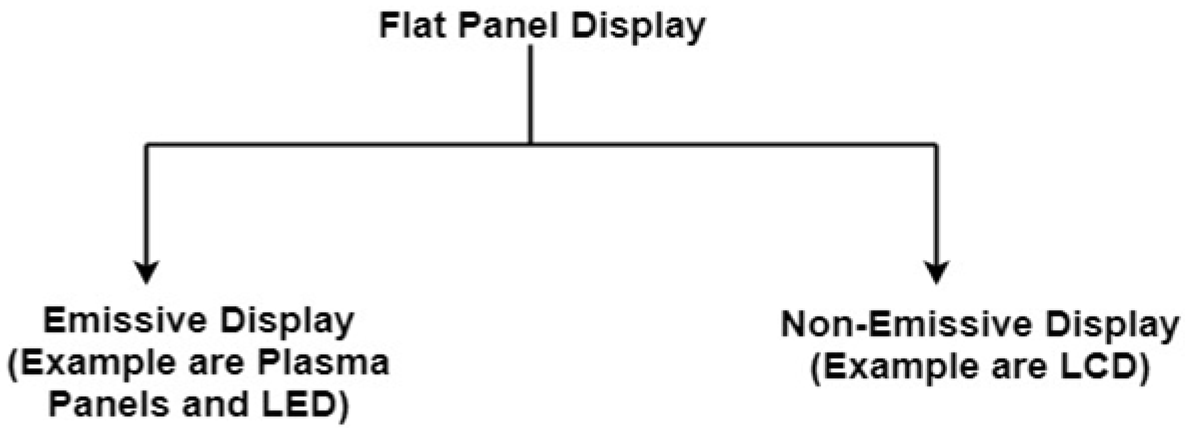


- **Advantages**
  - Produce realistic images
  - Million different colors to be generated
  - Shadow scenes are possible

- **Limitations**
  - low resolution
  - expensive

Flat Panel Displays

- The Flat-Panel display refers to a class of video devices that have reduced volume, weight and power requirement compare to CRT.
- **Example:** Small T.V. monitor, calculator, pocket video games, laptop computers, an advertisement board in elevator.



- **1. Emissive Display:** The emissive displays are devices that convert electrical energy into light. Examples are Plasma Panel, thin film electroluminescent display and LED (Light Emitting Diodes).
- **2. Non-Emissive Display:** The Non-Emissive displays use optical effects to convert sunlight or light from some other source into graphics patterns. Examples are LCD (Liquid Crystal Device).

Plasma Panel Display:

- Plasma-Panels are also called as Gas-Discharge Display. It consists of an array of small lights. Lights are fluorescent in nature. The essential components of the plasma-panel display are:
- **Cathode:** It consists of fine wires. It delivers negative voltage to gas cells. The voltage is released along with the negative axis.
- **Anode:** It also consists of line wires. It delivers positive voltage. The voltage is supplied along positive axis.
- **Fluorescent cells:** It consists of small pockets of gas liquids when the voltage is applied to this liquid (neon gas) it emits light.
- **Glass Plates:** These plates act as capacitors. The voltage will be applied, the cell will glow continuously.
- The gas will slow when there is a significant voltage difference between horizontal and vertical wires. The voltage level is kept between 90 volts to 120 volts. Plasma level does not require refreshing. Erasing is done by reducing the voltage to 90 volts.
- Each cell of plasma has two states, so cell is said to be stable. Displayable point in plasma panel is made by the crossing of the horizontal and vertical grid. The resolution of the plasma panel can be up to 512 * 512 pixels.

LED (Light Emitting Diode):

- In an LED, a matrix of diodes is organized to form the pixel positions in the display and picture definition is stored in a refresh buffer.
- Data is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light pattern in the display.

LCD (Liquid Crystal Display):

- Liquid Crystal Displays are the devices that produce a picture by passing polarized light from the surroundings or from an internal light source through a liquid-crystal material that transmits the light.
- LCD uses the liquid-crystal material between two glass plates; each plate is the right angle to each other between plates liquid is filled. One glass plate consists of rows of conductors arranged in vertical direction. Another glass plate is consisting of a row of conductors arranged in horizontal direction. The pixel position is determined by the intersection of the vertical & horizontal conductor. This position is an active part of the screen.
- Liquid crystal display is temperature dependent. It is between zero to seventy degree Celsius. It is flat and requires very little power to operate.

Three-Dimensional Viewing Devices

- Three-Dimensional Viewing Devices Graphics monitors for the display of three-dimensional scenes have been device using a technique that reflects a CRT image from a vibrating, flexible mirror.
- As the varifocal mirror vibrates, it changes focal length. These vibrations are synchronized with the display of an object on a CRT so that each point on the object is reflected from the mirror into a spatial position corresponding to the distance of that point from a specified viewing location.
- This allows us to walk around an object or scene and view it from different sides

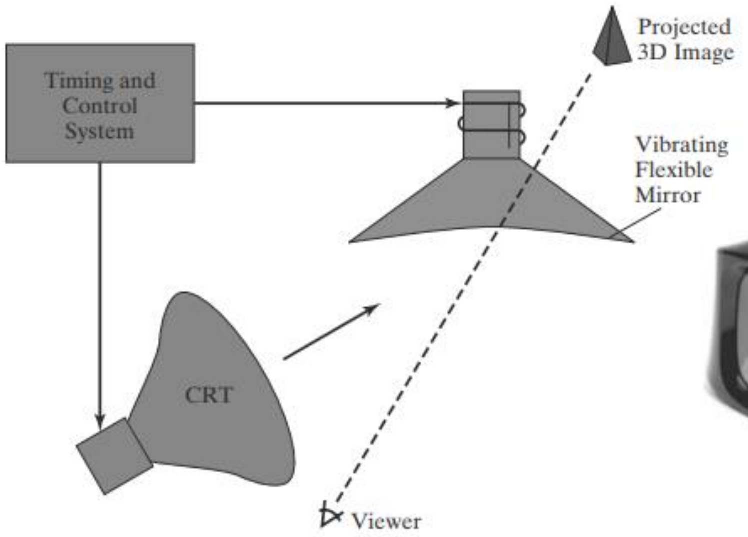


FIGURE 14
Operation of a three-dimensional display system using a vibrating mirror that changes focal length to match the depths of points in a scene.

FIGURE 15
Glasses for viewing a stereoscopic scene in 3D. (*Courtesy of XPAND, X6D USA Inc.*)

Graphics Software

- Interactive graphics allow users to make change over the displayed objects
- There are two general classifications for graphics software:
  I. **General programming packages**
  II. **Special-purpose application packages**

General programming packages

- **C, FORTRAN, Java** etc. contain graphics functions that can be used with high level programming languages

- **Open GL (Graphics library)**
  - A general-purpose graphics package provides users with a variety of functions for creating and manipulating pictures.
  - These graphic functions include tools for generating picture components, setting color, selecting views, and applying transformations.

Special-purpose application packages

- Specifically designed for particular applications
- **Maya, CINEMA 4D** are particularly used for animations
- Different types of **CAD** applications are designed for medical and business purposes
- Painting programs for artist
- These are primarily oriented to non-programmers

Software standards

- **Benefits of Standardized Graphics Functions**
  - **Independence**: Set of specifications independent of any programming languages
  - **Ease of Movement**: Software can be easily transferred between different hardware systems
  - **Versatility**: Usable in various implementations and applications
  - **Consistency**: Standardized functions ensure consistent performance across different systems
  - **Flexibility**: Facilitates the use of graphics software in diverse environments
  - **Efficiency**: Simplifies the development and deployment process by using common standards

Graphical Kernel System (GKS)

- GKS was the first graphics software standard adopted by the international standards organization (ISO)
- Provides standardized functions for graphical output across different hardware platforms
- It was originally designed as a 2-dimensional graphics package.
- GKS supports the grouping of logically related primitives such as; lines, polygons, character strings
- GKS was widely adopted in the 1980s and 1990s for developing graphical applications in various domains

Programmer’s Hierarchical Interactive Graphics System (PHIGS):

- It is an extension of GKS
- Increased capabilities in object modeling, color specifications, surface rendering, and picture manipulations are provided in PHIGS
- PHIGS include all primitives supported by GKS, in addition it also includes geometric transformations (***Scaling, Translation, and Rotation***)
- Widely used in the 1980s for interactive 3D graphics applications

PHIGS+

- Enhanced version of PHIGS with additional features and improvements
- 3-d surface shading capabilities are added to the PHIGS

THANK YOU