Computer Graphics and Multimedia

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Course Outline

- Course details:
  - MCA 3rd Semester
  - Course Code & Name: MCA-223 - Computer Graphics and Multimedia
  - No of credits: 3
- Instructor details:
  - Name: Dr. S. Suresh, Assistant Professor
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- Text book:
  - Computer Graphics (Principles and Practice) by Foley, van Dam, Feiner and Hughes, Addisen Wesley (Indian Edition).
  - Computer Graphics by D Hearn and P M Baker, Printice Hall of India (Indian Edition)
  - Computer Graphics: Principles and Practice (3rd Edition) by John F. Hughes et al., Addisen Wesley

What is Computer Graphics?

- Creation, Manipulation and Storage of geometric objects (modelling) and their images (rendering).
- Display those images on screens or hardcopy devices
- Image processing
- Others: GUI, Haptics, Displays (VR)…

What is Computer Graphics?

- Computer graphics are graphics created by computers and, more generally, the representation and manipulation of pictorial data by a computer.

  - Wikipedia

- "Computer graphics is the science and art of communicating visually via a computer's display and its interaction devices".

  - Foley et al.

History

- The phrase “Computer Graphics” was coined in 1960 by William Fetter, a graphic designer for Boeing.
- The field of Computer Graphics developed with the emergence of computer graphics hardware.

Computer Graphics

- Computer graphics is a cross-disciplinary field in which physics, mathematics, human perception, human-computer interaction, engineering, graphic design, and art all play important roles.
  - We use physics to model light and to perform simulations for animation.
  - We use mathematics to describe shape.
  - Human perceptual abilities determine our allocation of resources—we don't want to spend time rendering things that will not be noticed.
  - We use engineering in optimizing the allocation of bandwidth, memory, and processor time.
  - Graphic design and art combine with human-computer interaction to make the computer-to-human direction of communication most effective.

Types of Computer Graphics

- Non interactive
  - It's known as passive computer graphics, the observer has no control over the image.
  - Familiar example of this type of computer graphics includes TV.
- Interactive
  - Interactive computer graphics involves a two way communication the computer and user.
  - This helps the user to interact with the system.
  - The computer receives the signals from the input devices and can modifies the displayed picture appropriately

Applications

- Can be used in many disciplines
  - Charting, Presentations, Drawing, Painting and Design, Image Processing and Scientific Visualization are some among them.
- Paint Programs
- Illustration/design programs
- Animation software
- CAD software
- Desktop publishing

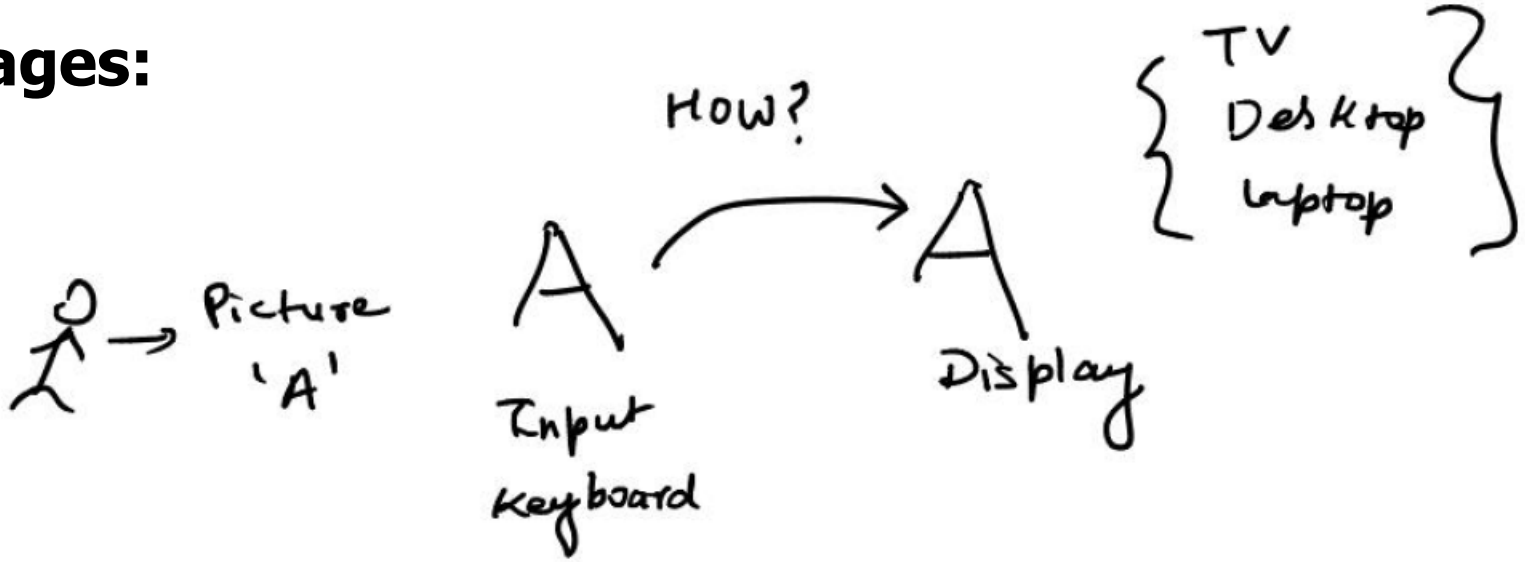
Computer Graphics

Overview of Graphics Systems

- Images
- Hardware
  - Input Devices
  - Output Devices
  - GPU
  - Memory/Frame Buffer
- Software
  - OS
  - Graphics Libraries/APIs
    - OpenGL
  - Graphic Applications

Computer Graphics

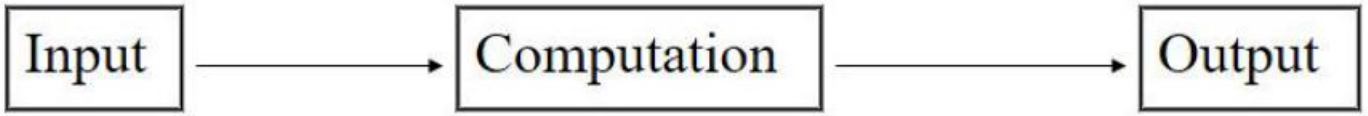
Images:



TV: CRT → Cathode Ray Tube

Computer Graphics

Hardware Pipeline

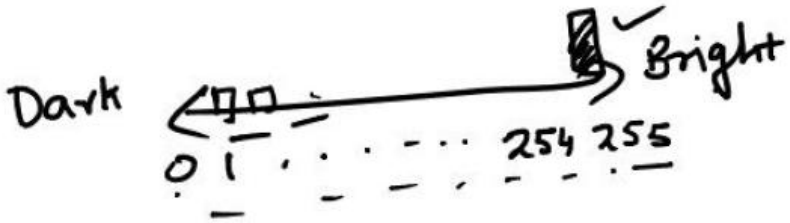


We want to draw a rectangle, how do we describe it to a computer?

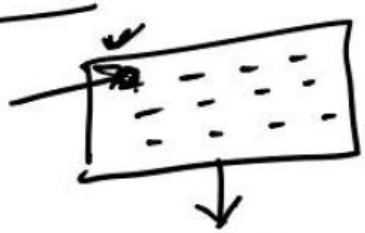
Model (n) - Object description that a computer understands.

Computer Graphics

Images:



8 bit image : $2^8 = 256$ intensity range $[0 \rightarrow 255]$



pixel → Picture Element

16 bit image : $2^{16} = X$

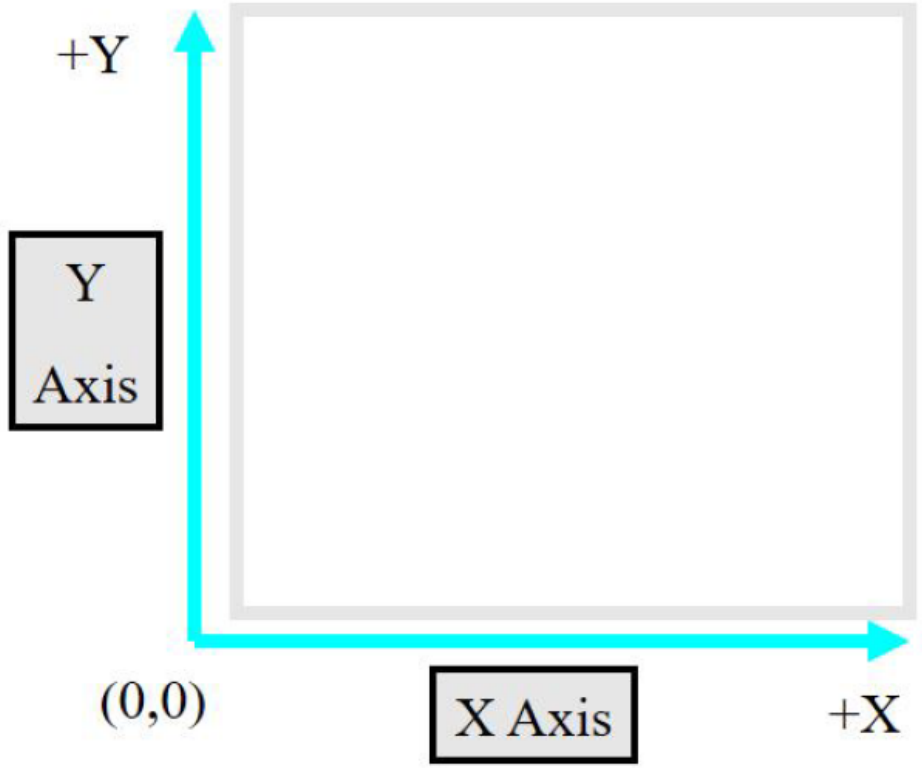
$[0 \quad X-1]$

Computer Graphics

Images:

Two Dimensional Images

- Images are two dimensional shapes.
- The two axes are labeled as X (horizontal), and Y (vertical).

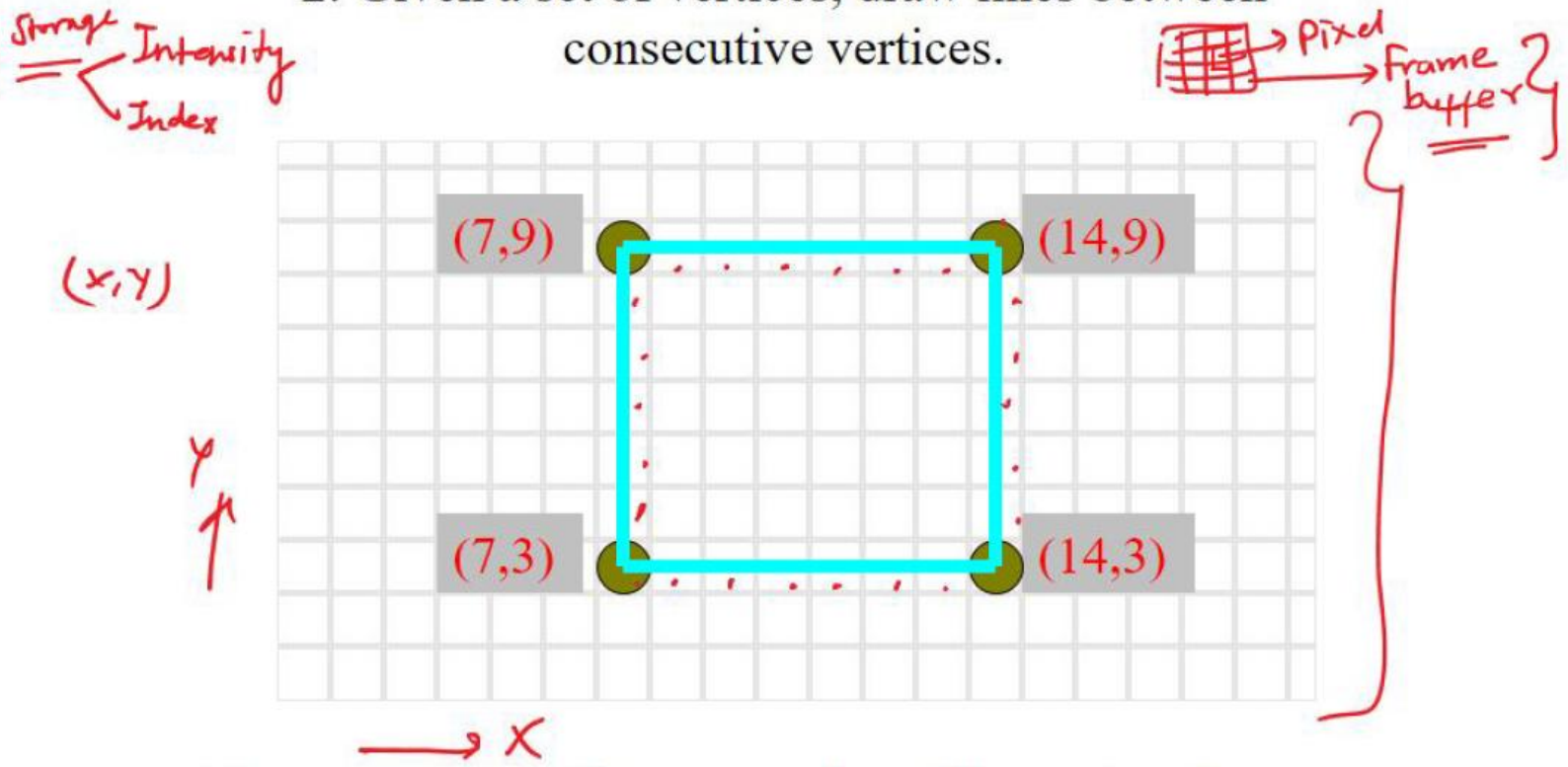


Computer Graphics

Images:

1. Define a set of points (vertices) in 2D space.

2. Given a set of vertices, draw lines between consecutive vertices.



Vertex is a point in two or three dimensional space.

Computer Graphics

Images:

Bit depth

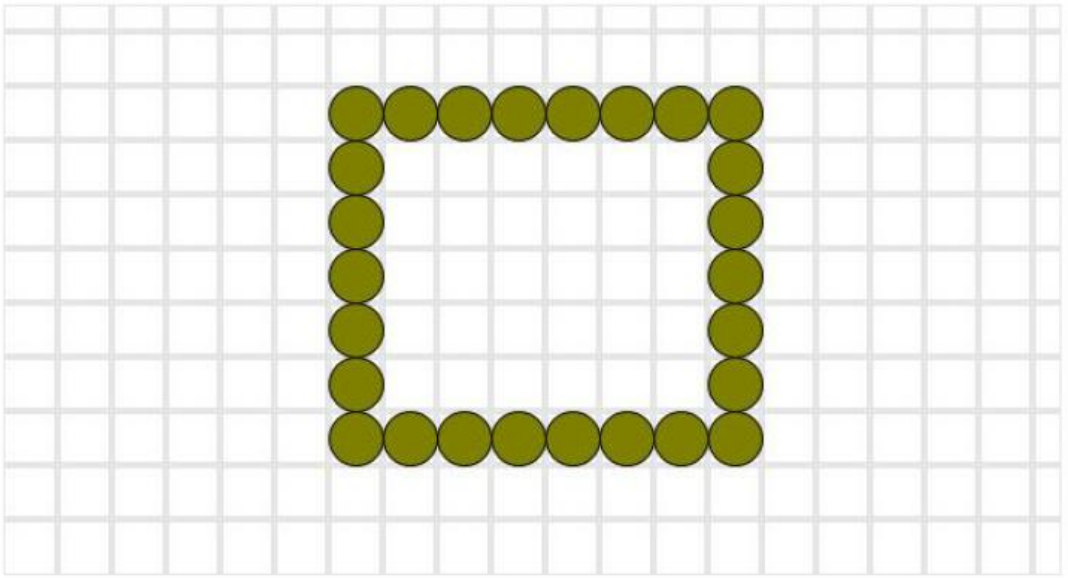
8 bit → [0 ... 255] intensity

2^8 256

16 bit → 2^{16} → [0 ...]

Gray levels

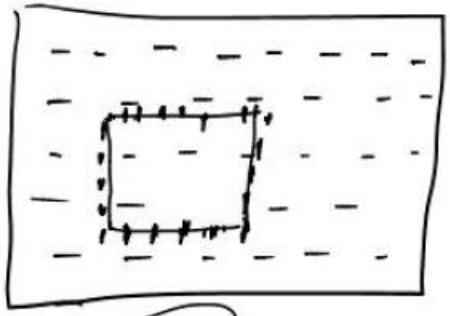
Record every position

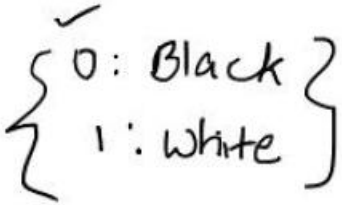


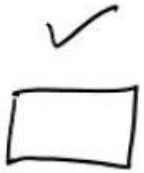
Bitmap - A rectangular array of bits mapped one-to-one with pixels.

Computer Graphics

Images:







1 → Display

0 and 1

Black and White → Absense of color

240 → intensity value

8 bit image :

([0 ...])

Image

Binary Image

Bit map

Pix map

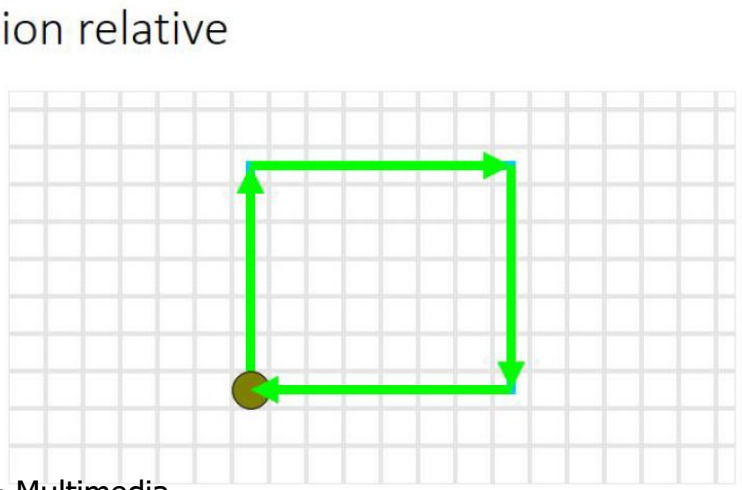
Color Image or Gray Scale Image

(One bit per pixel)

(Multiple bits per pixel)

Computer Graphics

- Position relative
  - In computer graphics, "position relative" typically refers to relative positioning, a method of placing elements or objects based on their normal or original position within a given coordinate system or layout.
  - Instead of defining an object's position explicitly from a fixed origin (like the top-left corner of a screen or a scene's origin), relative positioning defines offsets from where the object would naturally be placed.

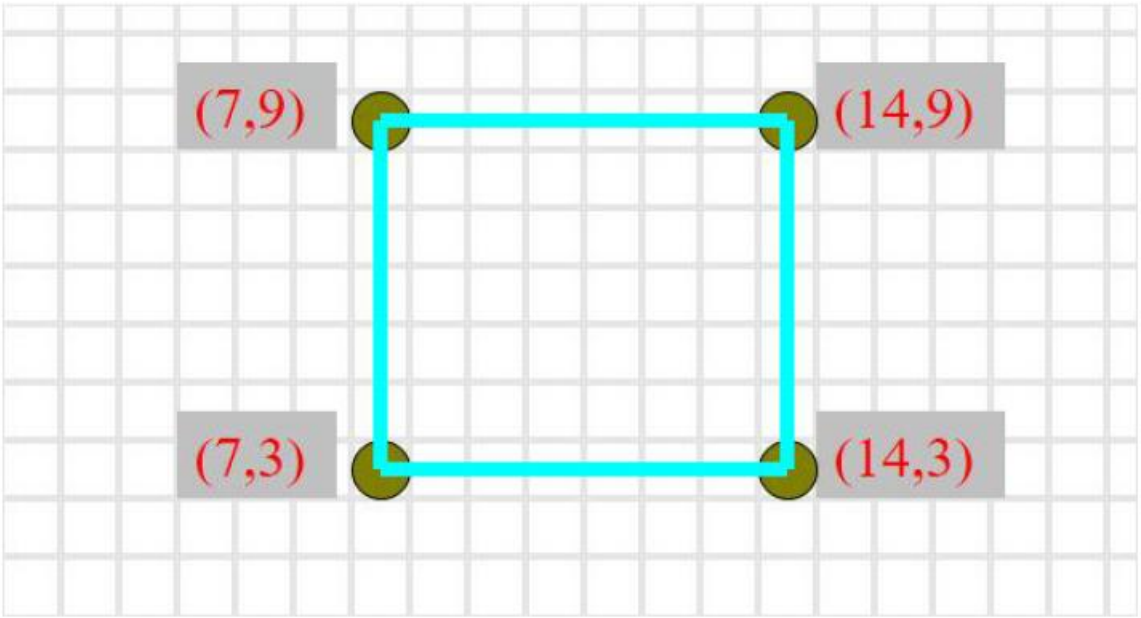


Computer Graphics

Images:

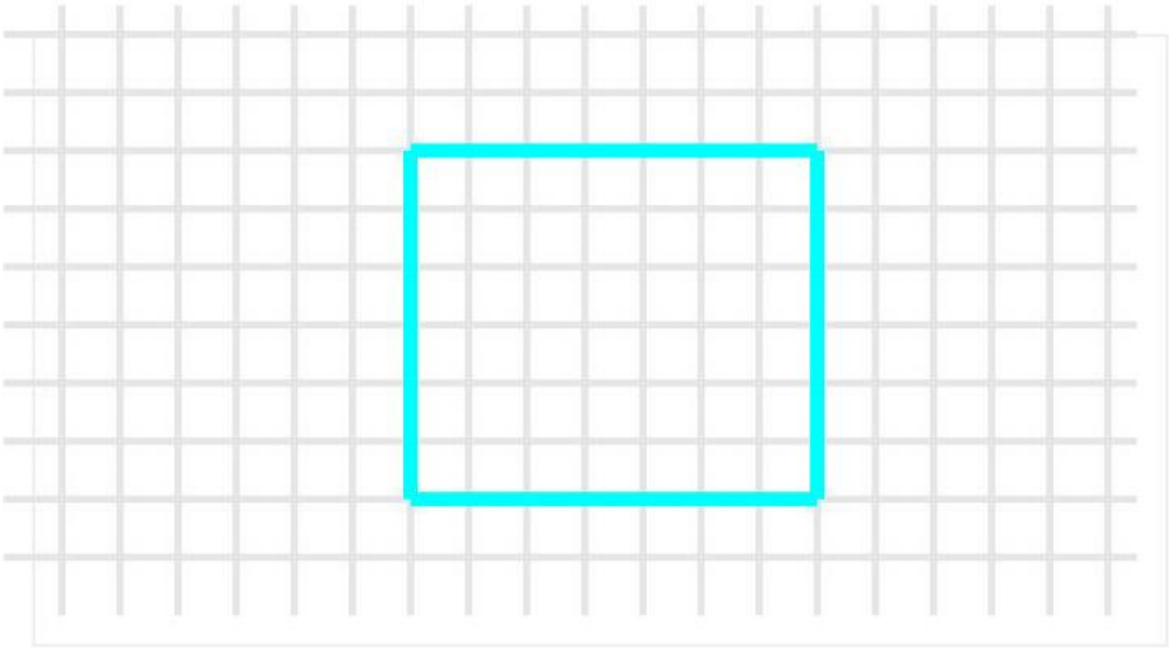
Model file for rectangle

- v 4 e 4
- 7 3
- 7 9
- 14 9
- 14 3



Computer Graphics

How do we store this?



We need to allocate memory to store the results of the computation stage.

Computer Graphics

Framebuffer

Framebuffer –

- It is a block of memory, which is dedicated to the graphics output.
- That holds the contents of which will be displayed.

Pixel - One element of the framebuffer

Computer Graphics

Framebuffer in Memory

- If we want a framebuffer of 640 pixels by 480 pixels, we should allocate

  framebuffer = 640*480 bits

- How many bit should we allocate?

  Q: What do more bits get you?

  A: More values to be stored at each pixel.

What if we want to store something other than 0 or 1?

Computer Graphics

Framebuffer bit depth

- **bit depth** - Number of bits allocated per pixel in a buffer.
- Remember, question is "*How much memory do we allocate to store the color at each pixel?*"

Computer Graphics

Data Type Refresher

- *bit* - 0 or 1, which can be represented in two unique values
- *byte* - 8 bits, 256 values
- *word* - 32 bits, 4,294,967,296 values

Computer Graphics

Graphic Card Memory

- How much memory is on our graphic card?
  - 640 * 480 * 32 bits = 1,228,800 bytes
  - 1024 * 768 * 32 bits = 3,145,728 bytes
  - 1600 * 1200 * 32 bits = 7,680,000 bytes

Screen Resolution – It is a measurement of number of pixels on a screen (m X n)

m - Horizontal screen resolution

n - Vertical screen resolution

Computer Graphics

- Graphics Processing Unit (GPU):
  - A specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images, frames, or animations.

- Frame Buffer/Graphics Memory:
  - Dedicated memory on the graphics card that stores the pixel data for the image being displayed.

Computer Graphics

Graphics input devices

- Keyboard
- Mouse
- Trackball and Spaceball
- Joystick
- Image scanner
- Touch panel

Graphics input devices

- Monitors (CRT, LCD, LED): The primary visual display.
- Printers/Plotters: For hardcopy output.
- Projectors: To display images on a large surface.

Computer Graphics

- Input Devices:

Locator Devices

When queried, locator devices return a position and/or orientation.

- Mouse (2D and 3D)
- Trackball
- Joystick (2D and 3D)

Computer Graphics

- Input Devices:

Contd...

- Tablet
- Virtual Reality Trackers
  - Data Gloves
  - Digitizers

Computer Graphics

- Input Devices:

Keyboard

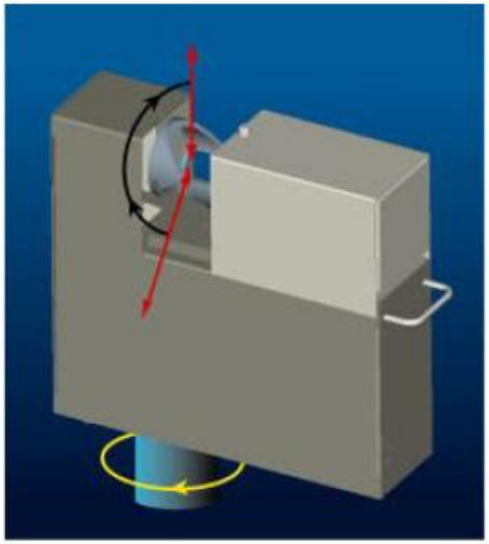
- Text input
  - CAD/CAM
  - Modeling
- Hard coded
  - Vertex locations are inserted into code

Computer Graphics

- Input Devices:

Scanners

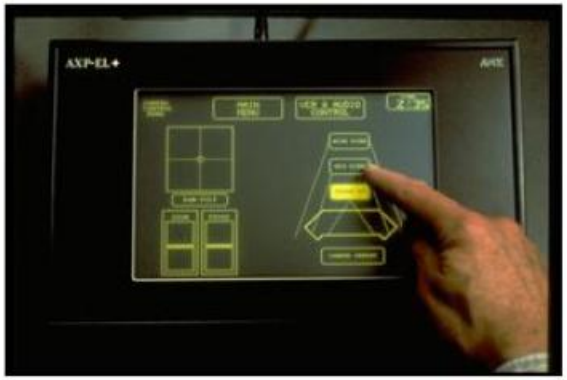
- Image Scanners
  - What type of data is returned? **Bitmap**
- Laser Scanners
  - Emits a laser and returns 3D point
- Camera based
  - Examine camera image and try to figure out vertices from them.



Computer Graphics

- Input Devices:

  - Light Pens
  - Voice Systems
  - Touch Panels
  - Camera/Vision Based
  - **Which is best among these all devices?**



Computer Graphics

- Output Devices:
  - Monitors (CRT, LCD, LED): The primary visual display.
  - Printers/Plotters: For hardcopy output.
  - Projectors: To display images on a large surface.

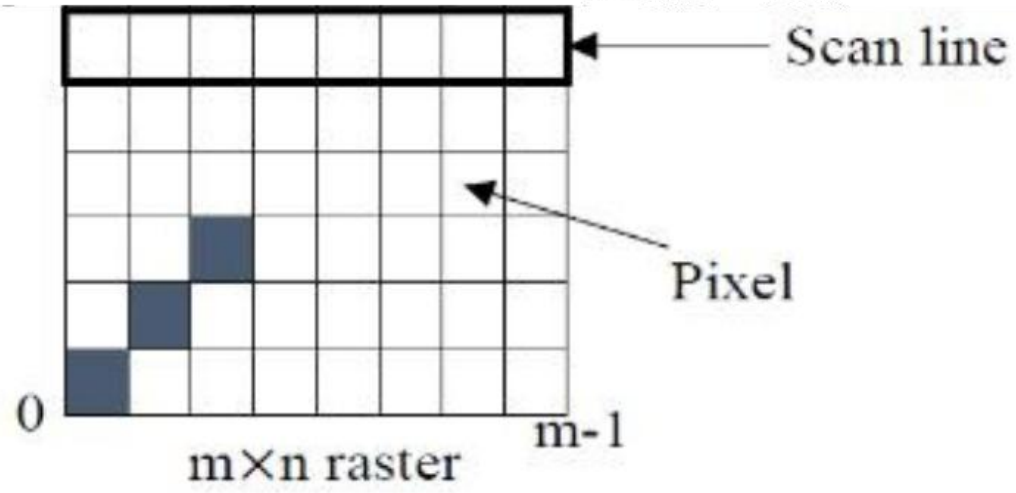
- Raster Displays
- Random Displays/Vector Displays

Computer Graphics

- In computer graphics object are presented as a collection of discrete picture element.
- Picture element = pixel
- Pixel is the smallest graphical picture or unit represented on the computer screen.
- Graphics should be generated by controlling pixel.
- The control is achieved by setting the intensity and color of the pixel which compose the screen.
- The process of determining the appropriate pixels for representing pictures or graphics object is known as *rasterization*.

Computer Graphics

- Raster: rectangular array of points and dots.
- Pixel or picture element: one dot or picture element of the raster.
- Scan line: A row of pixel.



- Note: Raster device coordinate can have only integer values. We don't have any pixel like 1.8, 2.9 etc.

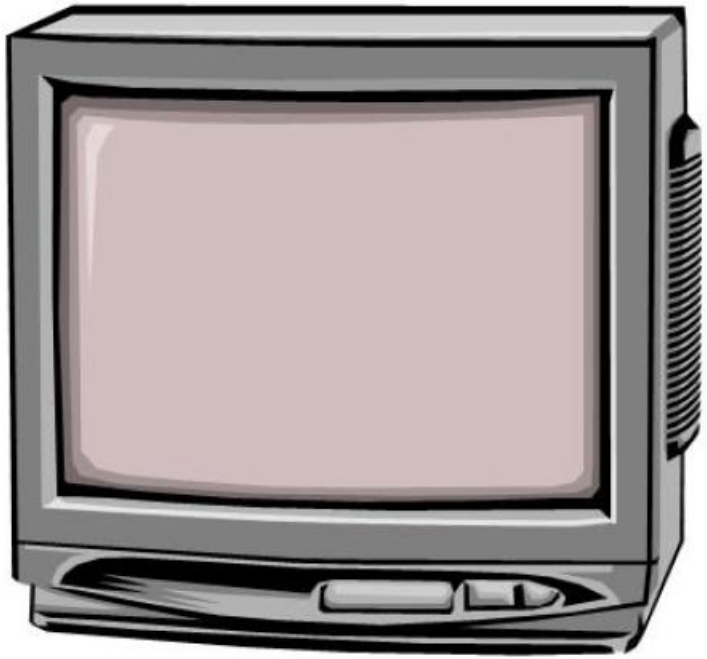
Raster displays vs Vector displays

- **Raster displays**
  - Use a grid of pixels
  - File formats - JPEG, PNG, GIF, etc.
  - Strengths:
    - Complex images: They are capable of displaying complex, detailed images with a wide range of colors and shading.
    - Photo-realistic images: They are well-suited for displaying photographic images and other images with continuous tones.
    - Color editing: Raster images allow for detailed color editing and manipulation.
  - Weaknesses:
    - Resolution-dependent: Raster images lose quality when scaled up or down, becoming pixelated or blurry.
    - Large file sizes: They can have large file sizes, especially for high-resolution images

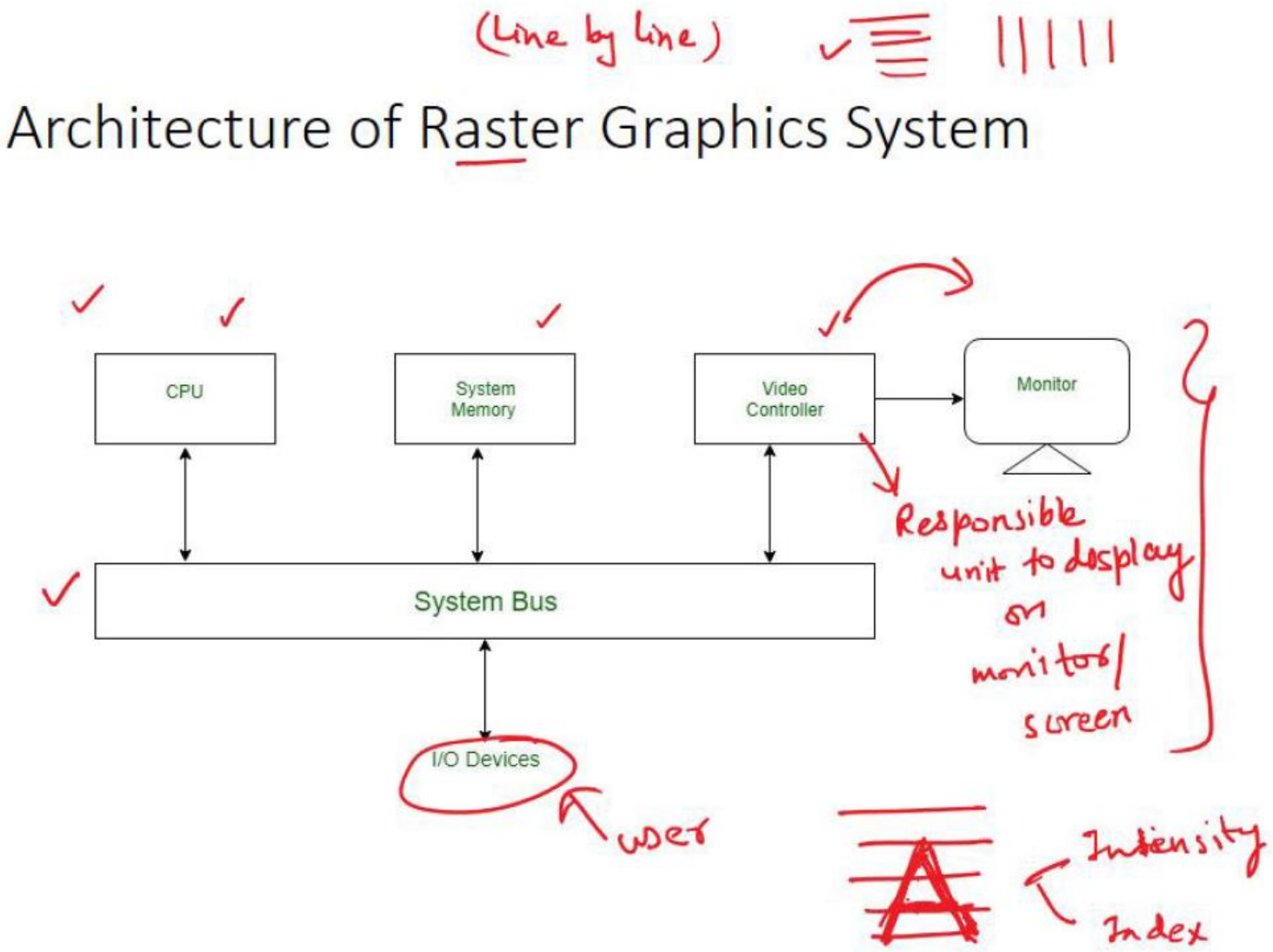
Raster displays

Raster Displays

- Cathode Ray Tubes (CRTs)
  - Most tube monitors
  - Very common
  - Big and bulky
- Liquid Crystal Displays (LCDs)
  - Transmissive
    - Laptops
    - Flat panel monitors
  - Reflective
    - Wrist watches

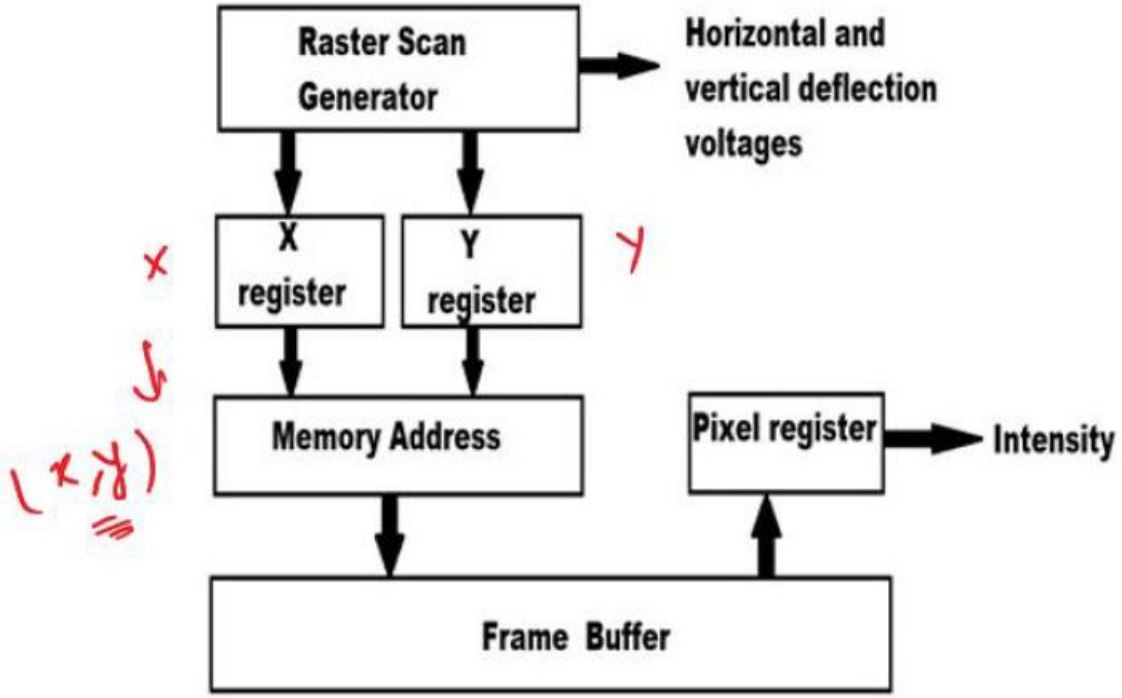


Raster displays



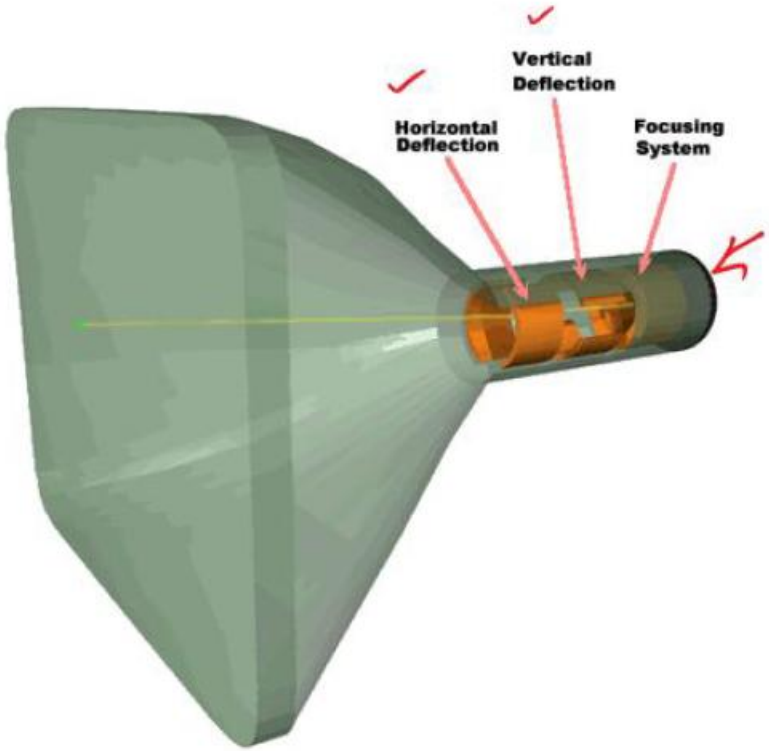
Raster displays

Video Controller Refresh Operations



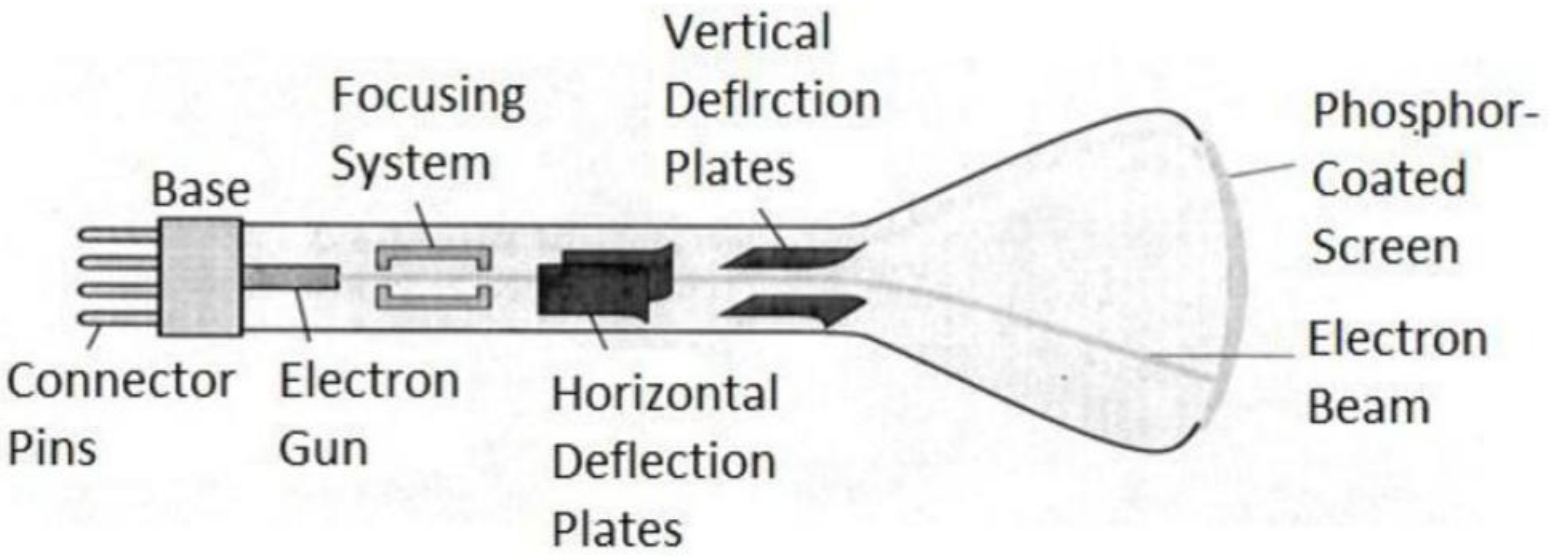
Raster displays

Cathode Ray Tubes (CRTs)



- Heating element.
- *Phosphorous* coated screen.
- Electrons are boiled off the filament and drawn to the focusing system.
- The electrons are focused into a beam and *shot* down the cylinder.
- The deflection plates *aim* the electrons to a specific position on the screen.

Raster displays



Raster displays

CRT Screen

- The screen is coated with phosphor, three colors for a color monitor, one for monochrome.
- For a color monitor, three guns light up red, green, and blue phosphors.

R G B → Primary Colors

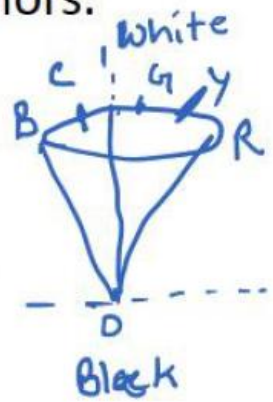
Yellow, Cyan, Magenta

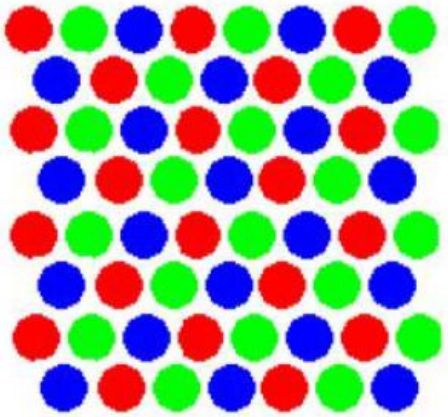
Secondary Colors

RGB Model

R G B

COLOR	R	G	B
Red	1	0	0
Green	0	1	0
Blue	0	0	1
Yellow	1	1	0
Cyan	0	1	1
Magenta	1	0	1
White	1	1	1
Black	0	0	0





Raster displays

RR: Scanning full screen at a time

Flickering

Beam Movement

- **Scan line** –

  One row on the screen

- **Interlace vs non-interlace** –

  Each frame is either drawn entirely, or as two consecutively drawn fields that alternate horizontal scan lines.

- **Vertical retrace** –

  The motion of the beam moving from the bottom of the image to the top.

- **Refresh rate** –

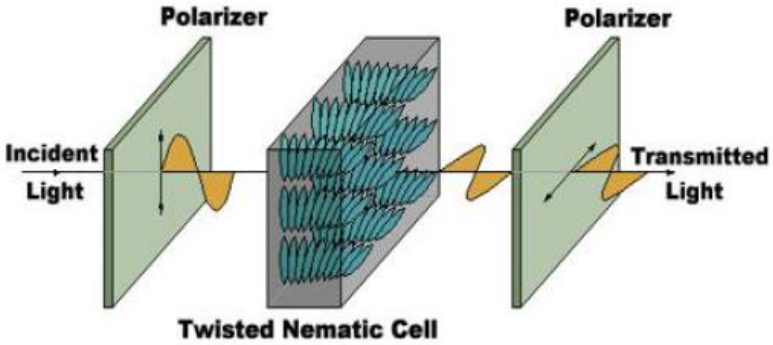
  How many frames are drawn per second.

  TV is 30 Hz, monitors are at least 60 Hz.

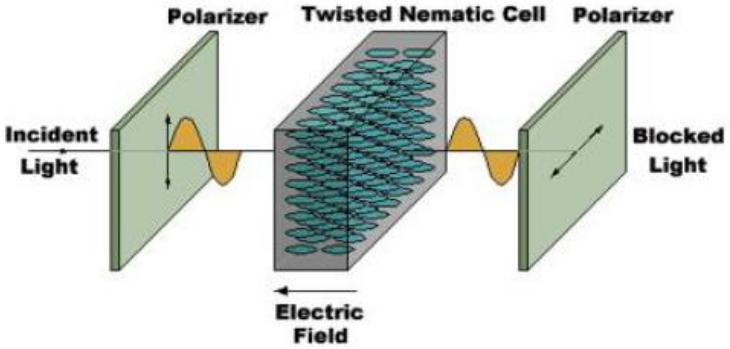
Raster displays

Liquid Crystal Displays (LCDs)

LCDs have cells that either allow light to flow through or block it.



Transmitted light (ON State)



Blocked light (OFF State)

Raster displays

Contd...

- Liquid crystal displays use small flat chips which change their transparency properties when a voltage is applied, which level of voltage controls gray levels.
- LCD elements are arranged in an n x m array, known as LCD matrix.
- LCD elements do not emit light.
- It uses backlight behind the LCD matrix.
- Color is obtained by placing filters in front of each LCD element.
- Usually black space between pixels are provided to separate the filters.
- Image quality is dependent on viewing angle.

Raster displays

Advantages of LCD

- Flat
- Light-weighted
- Low power consumption

Vector displays

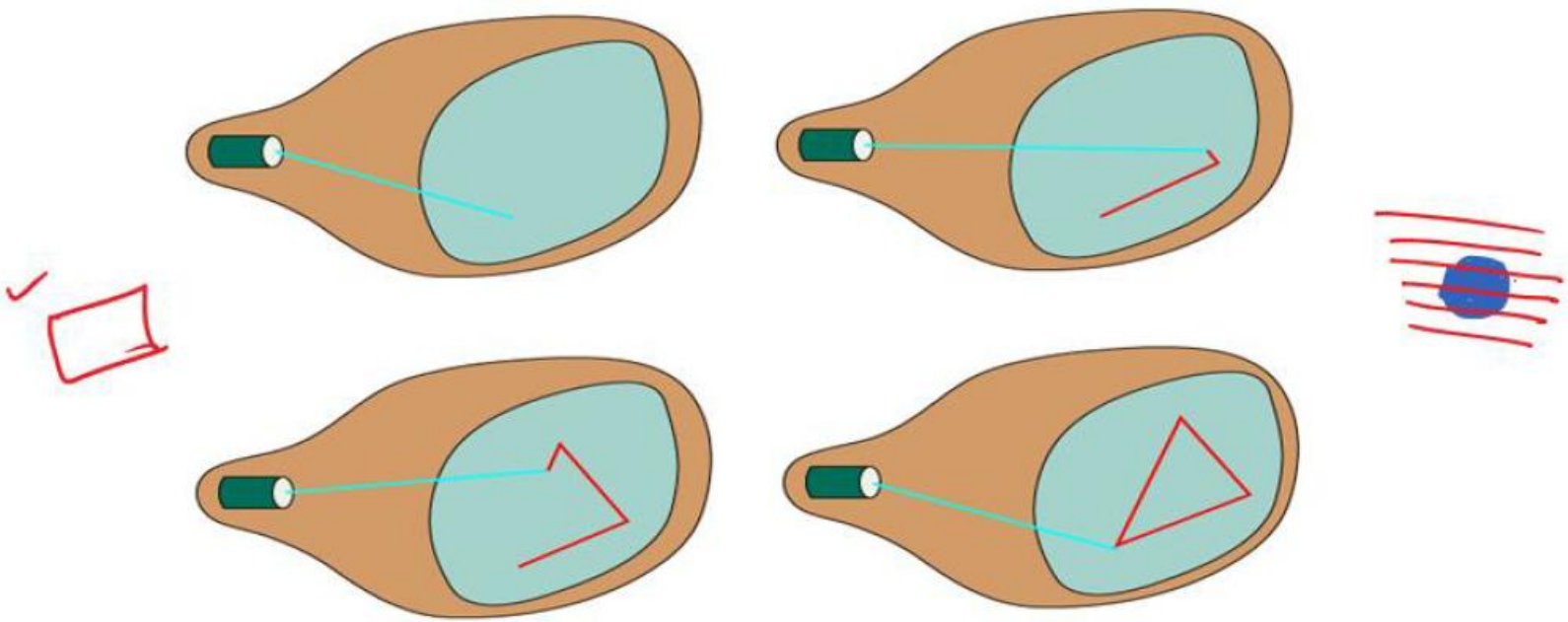
Vector Displays

- Unlike CRTs, vector displays have a single gun that is controlled to draw a line
- You may think of having a *very fast* drawing pen
- Pros:
  - Diagrams
  - Only draw what user needs
- Cons:
  - No fill objects
  - Slows with complexity

Vector display system - Graphical output system is based on strokes (as opposed to pixels).

Also known as: *Random, Calligraphic,* or *Stroke* Display.

Vector displays



Vector displays

- **Vector displays**
  - Draw lines and shapes directly based on mathematical equations
  - File formats - PDF, EPS, etc.
  - Strengths:
    - Resolution-independent: can be scaled to any size without losing quality.
    - Small file sizes: They generally have smaller file sizes than raster images, especially for simple shapes and lines.
    - Clean lines and shapes: offer clean, crisp lines and shapes, making them ideal for illustrations, logos, and other designs where sharp edges are important.
  - Weaknesses:
    - Limited complexity: may not be suitable for displaying highly detailed, photographic-like images.
    - Less realistic: may not be able to reproduce the subtle color variations and shading found in raster images

Raster vs Vector displays

Difference between Raster Scan and Random Scan

Sr. No.	Characteristic	Raster Scan	Random Scan
1.	Resolution	Low	High
2.	Cost effective	Less	More
3.	Solid structure	Easy	Tough
4.	Refresh Rate	Does not depend on the image	Depends on resolution
5.	Screen display	Whole screen is displayed	Only screen with view is displayed
6.	Restrictions on drawing	Suitable for realistic pictures	For line or easy shapes
7.	Interlacing	Used	Not used

Computer Graphics

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

- You have probably seen that in your own computer settings, you have monitor resolution of 640 X 480, 800 X 600, 1024 X 768, 1152 X 864, 1280 X 1024.

Computer Graphics

- Software:
  - **Operating System (OS):** Provides the fundamental framework for running graphics applications.
  - **Graphics Libraries/APIs:** Provide functions and tools for programmers to create and manipulate graphics.
  - **Graphics Applications:** Software used by end-users for tasks like image editing, 3D modeling, animation, and computer-aided design (CAD).
  - **OpenGL:** (Open Graphics Library) is a cross-platform, cross-language application programming interface (API) for rendering 2D and 3D vector graphics. It provides a standard set of commands and functions that graphics hardware can understand, allowing developers to create graphics applications that are independent of the underlying hardware. It acts as an interface between the graphics software and the GPU, enabling efficient rendering of complex scenes.

Computer Graphics

- Image resolution is the distance from one pixel to next pixel.
  - The unit image pixel is ppi (pixel per inch)
  - In normal PC monitor it ranges between 25 to 80 pixels per inch.
- Screen Resolution: It is the number of distinct pixels in each dimension that can be displayed.
  - For example, a computer with a display resolution of 1280 x 768 will produce a maximum of 98,3040 pixels

Computer Graphics

Aspect Ratio

- Aspect ratio is the ratio between width of an image and the height of an image.
  - It is normally shown by two numbers separated by colon, as in 4:3. Here, the primary number tells that the picture is 4 units wide and the subsequent number tells that the picture is 3 units high.

Computer Graphics

- Various kinds of Aspect Ratios
  - 1:1 (Square) Standard: Square displays are rarely utilized in gadgets and screens. The square video was promoted by versatile applications, for example, Instagram and has since been upheld by other significant social stages including Facebook and Twitter. It can fill about twice as much screen space contrasted with 16:9 one.
  - 4:3 Standard: standard has been being used for TVs since creation of moving picture cameras and numerous PC screens used to have similar aspect ratio.

Computer Graphics

- Various kinds of Aspect Ratios
  - 16:10(8:5) Standard: is an aspect ratio generally utilized for PC presentations and tablet PCs.
  - 16:9 Standard: is universal standard configuration of HDTV, non-HD computerized TV, and simple widescreen TV.
  - 1.85:1 Standard, 2:1 Standard, 2.35:1 and 2.39:1 Standard, Vertical Video Standard

Computer Graphics

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

Computer Graphics

- Q: Consider a RBG raster system is to be designed using 8inch by 10inch screen with a resolution of 100 pixels per inch in each direction.
- If 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 = 8inch x 10 inch
    - Pixel per inch(resolution) = 100
    - Total no. of pixel = (8*100)*(10*100) = 800000 pixels
    - Per pixel storage = 8 bit
    - Total storage required in frame buffer = 800000*8bits

    = 6400000 bits or 0.8 megabytes

Computer Graphics

- Q: Consider the different raster systems with resolutions of 640 x 480 and 1280 x 1024.
- What size is frame buffer (in bytes) for each of these systems to store 12 bits per pixel?

Computer Graphics

- Q: Consider the different raster systems with resolutions of 640 x 480 and 1280 x 1024.
- What size is frame buffer (in bytes) for each of these systems to store 12 bits per pixel?

- Solution
  - 640 x 480 x 12 bits / 8 = 450KB.
  - 1280 x 1024 x 12 bits / 8 = 1920KB.

Computer Graphics

- Q: Find out the aspect ratio of the raster system using 8 x 10 inches screen and 100 pixel/inch?

Computer Graphics

- Q: Find out the aspect ratio of the raster system using 8 x 10 inches screen and 100 pixel/inch?

- Solution

We know that,

$$\text{Aspect ratio} = \frac{\text{Width}}{\text{Height}}$$

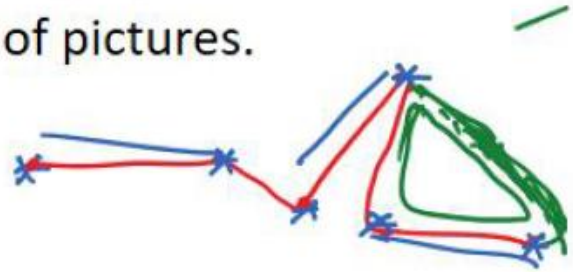
$$= \frac{8 \times 100}{10 \times 100} = 4 / 5$$

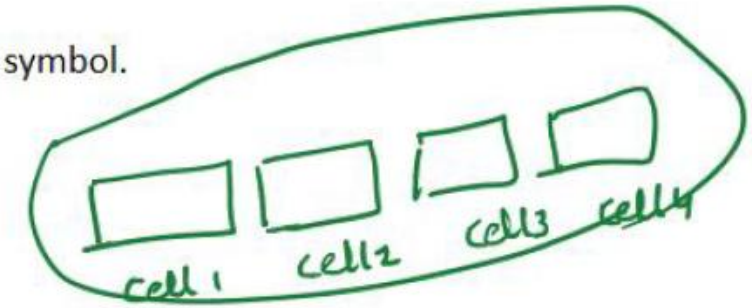
Aspect ratio =4 : 5

Computer Graphics

Graphical Kernel System (GKS)

- It is the first ISO standard for low-level computer graphics.
- It is used for the production and manipulation of pictures.
- The five main primitives in GKS are:
  - *polyline*:
    - It draws a sequence of connected line segments.
  - *polymarker*:
    - It marks a sequence of points with the same symbol.
  - *fill area*:
    - It displays a specified area.
  - *text*:
    - It draws a string of characters.
  - *cell array*:
    - It displays an image composed of a variety of colors.





Computer Graphics

Standard	Year (ISO/Release)	Scope	Type	Key Features
GKS (Graphical Kernel System)	1985 (ISO 7942)	2D graphics	Device-independent API	First ISO graphics standard; supports points, lines, polygons, text; standardized input/output
GKS-3D	1988 (ISO 8805)	3D graphics	Device-independent API	Adds 3D primitives, transformations, viewing, hidden surface removal
PHIGS (Programmer's Hierarchical Interactive Graphics System)	1989 (ISO 9592)	3D interactive graphics	Retained-mode API	Hierarchical object structures; supports dynamic updates and interaction
CGI (Computer Graphics Interface)	1990 (ISO 9636)	Interface layer	N/A	Standardizes communication between apps and graphics devices
CGM (Computer Graphics Metafile)	1992 (ISO/IEC 8632)	Graphics storage	Vector & raster	Portable metafile format for CAD, GIS, technical diagrams
VRML (Virtual Reality Modeling Language)	1997 (ISO/IEC 14772)	Web 3D graphics	Scene description language	Text-based; describes interactive 3D worlds; predecessor to X3D
X3D	2005 (ISO/IEC 19775)	Web 3D graphics	Scene description language	XML/VRML encoding; interactive 3D content on the web
OpenGL	1992 (Khronos Group)	2D & 3D graphics	Immediate-mode API	Cross-platform API; hardware accelerated rendering
WebGL	2011 (Khronos Group)	Browser 3D graphics	JavaScript API	Based on OpenGL ES; interactive 3D graphics in web browsers