Fundamentals of Computer Graphics

- **Evolution of Computer Graphics**
- **Input -Output Devices**
- **Video Display Devices**
- **Raster-Scan System**
- **Random-Scan Systems**

History of Computer Graphics

- First Generation (1951 - 1959)
  - UNIVAC (1951) (Universal automatic computer)
- Data was displayed on printers or hardcopy plotters
- Computers were “number crunchers”; hardware was expensive!
- First computer-driven display (Late 50s and early 60s)
  - attached to MIT’s Whirlwind I computer
  - display was CRT similar to one used in TV sets

- SAGE air-defense system (mid 50s) used command & control CRT
- used CRT display consoles on which operators identified targets with light pens

- Beginnings of modern interactive graphics attributed to Ivan Sutherland's doctoral work
  - ✓ presented work at Spring Joint Computer conference in 1963.
  - ✓ developed the Sketchpad drawing system.
  - ✓ the system included interactive techniques that used the keyboard and light pen for making choices, pointing, and drawing
  - ✓ the film showed Sutherland sketching a bolt on the screen.

- He formulated the ideas of
  - – display primitives (lines, polygons, arcs, characters)
  - – constraints on primitives
  - – developed algorithms for dragging, transforming(rotating, scaling, translating)
  - – introduced data structures for storing hierarchies built up via easy replication of standard components

- He is considered to be the ***founder of the computer graphics field***
- Because of his work, CAD & CAM became attractive
- By the mid-sixties, much research was being done

Computer Graphics of 60’s

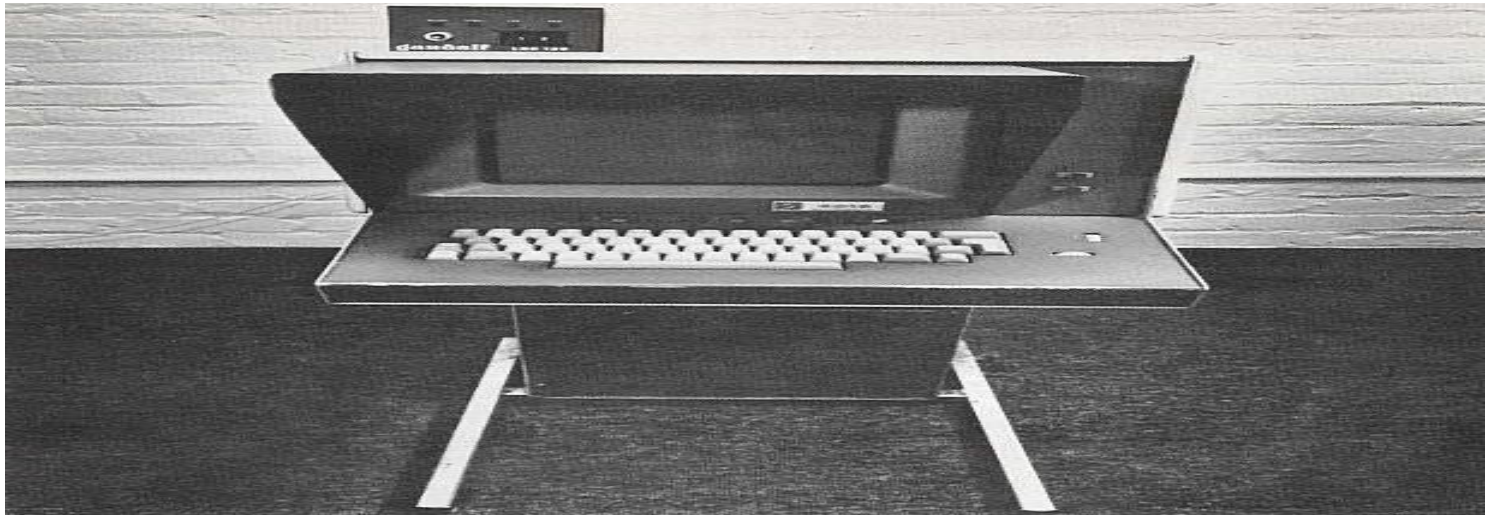
- large scale, expensive computing resources needed
- About 1965, IBM brought out the first widely available interactive computer graphics terminal
  - ✓ vector graphics display
  - ✓ sold for more than $100,000
  - ✓ only elite designers could use the display system

More developments

•The next landmark was a special type of CRT produced by Tektronix - the direct-view storage tube (DVST)

• Introduced in 1968

- ✓ complete with keyboard, mouse, simple computer interface for $15,000
- ✓ made interactive computer graphics affordable



Where did graphics go next?

•By late 60’s many researchers were concerned with dynamic graphics.
• Realistic flight simulation applications were needed to make them realistic, solid colored surfaces were needed (not wireframe)
• TV raster displays were used to create such images
• Systems built by GE for NASA were probably the earliest examples of such displays

Where did graphics go next?

•Xerox Palo Alto Research Center designed a new graphics based personal minicomputer called the Alto

• Design was based on:

- ✓ cost of computing falling - every "knowledge worker" should have a personal computer
- ✓ Alto computers should be connected for communication & resource sharing
- ✓ interface between user & computer should be graphical
- ✓ graphics display should be based on raster-graphics technology – a very bold idea

More hardware developments

- PC’s in the 80’s

✓ costs decrease drastically

✓ built-in raster displays

✓ bitmap graphics used

Software developments

- Sketchpad graphics
- Early days software was non transportable at the assembly language level
- Push in 70’s for high-level, machine- and device-independent graphics subroutine packages
- The awareness of the need for standards culminated in
  - ✓ specification of the **3D Core Graphics System**
  - ✓ produced by an ACM SIGGRAPH Committee in late 70’s
  - ✓ used as input to official standards projects within both ANSI and ISO
- First graphics standard was GKS (1985)
  - ✓ like Core but 2D
- PHIGS (Programmer’s Hierarchical Interactive Graphics System) was a 3D extension of GKS became an ANSI standard in 1988

More Software

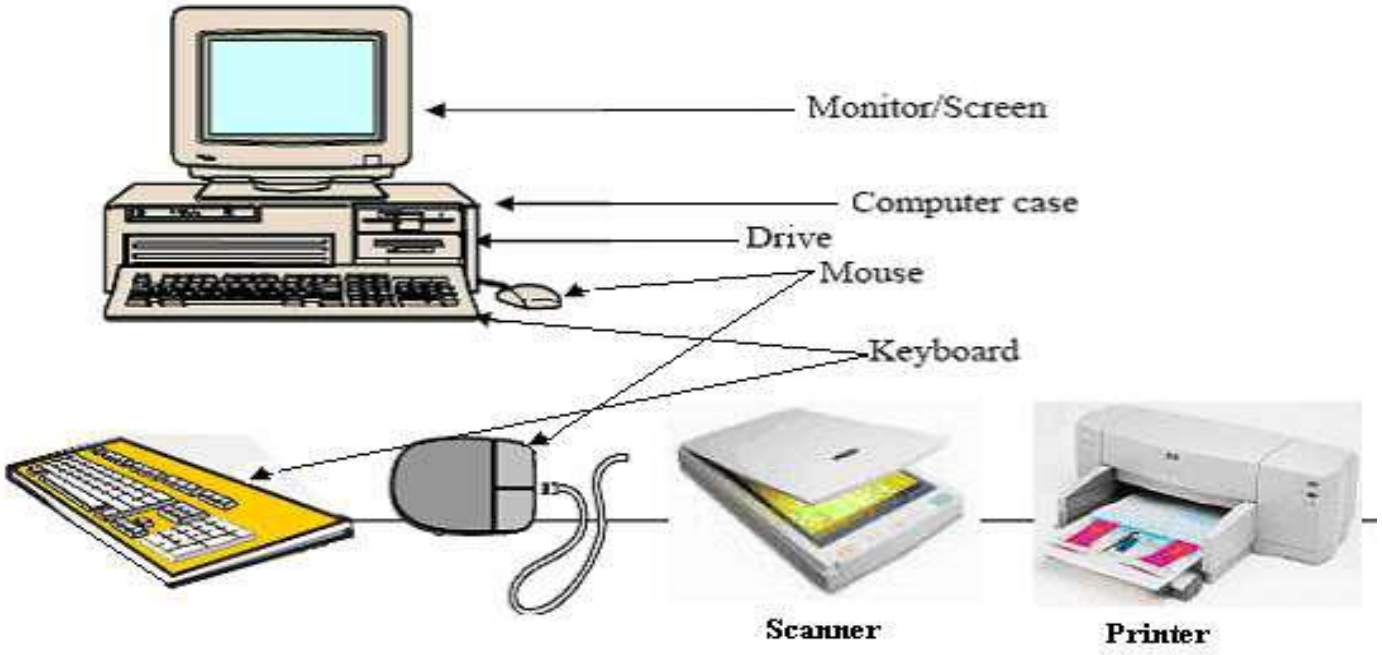
- OpenGL was introduced by SGI in 1992
  - ✓ OpenGL is the “Assembler Language” of Computer Graphics
  - ✓ has portable, interactive 2D and 3D graphics applications
  - ✓ low-level, vendor-neutral software interface
  - ✓ broad platform accessibility in the industry

- Sun formally announced Java in 1995
  - ✓ Developed by James Gosling (originally called Oak)
  - ✓ Considered to be a software development platform

- Includes graphics & windowing capabilities
  - ✓ Java AWT (Abstract Windowing Toolkit)
  - ✓ Java 2D
  - ✓ Java 3D

Input and Output Devices

- Do you ever wonder how information gets in your computer and how comes out in a form you can use? So, It is only possible with the help of Devices.



What is Devices?

- It can be defined as the components or peripherals which are attached to the computer to enter the data and get the desired

  result.
- Examples:-

  Monitor, Keyboard, Mouse, Printer etc.

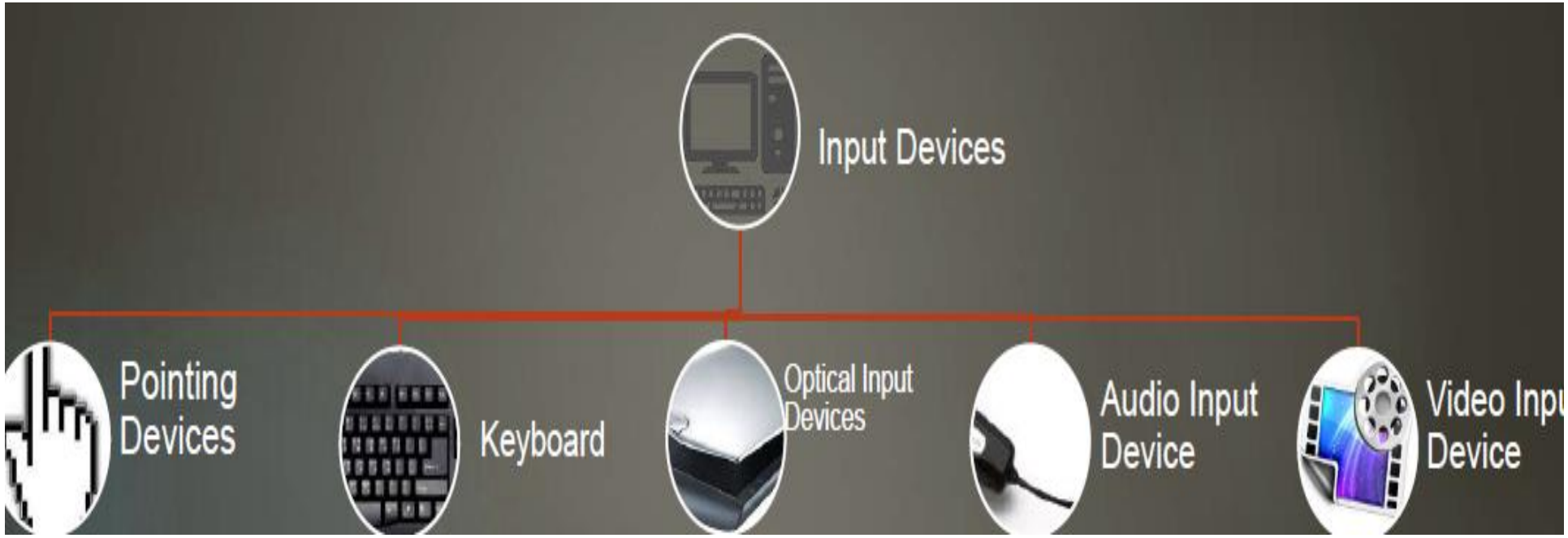
- **Type of Devices:**

  Input Device

  Output Devices

Input Devices

- It is an Electromechanical Device that can be used to enter data and instructions to the computer



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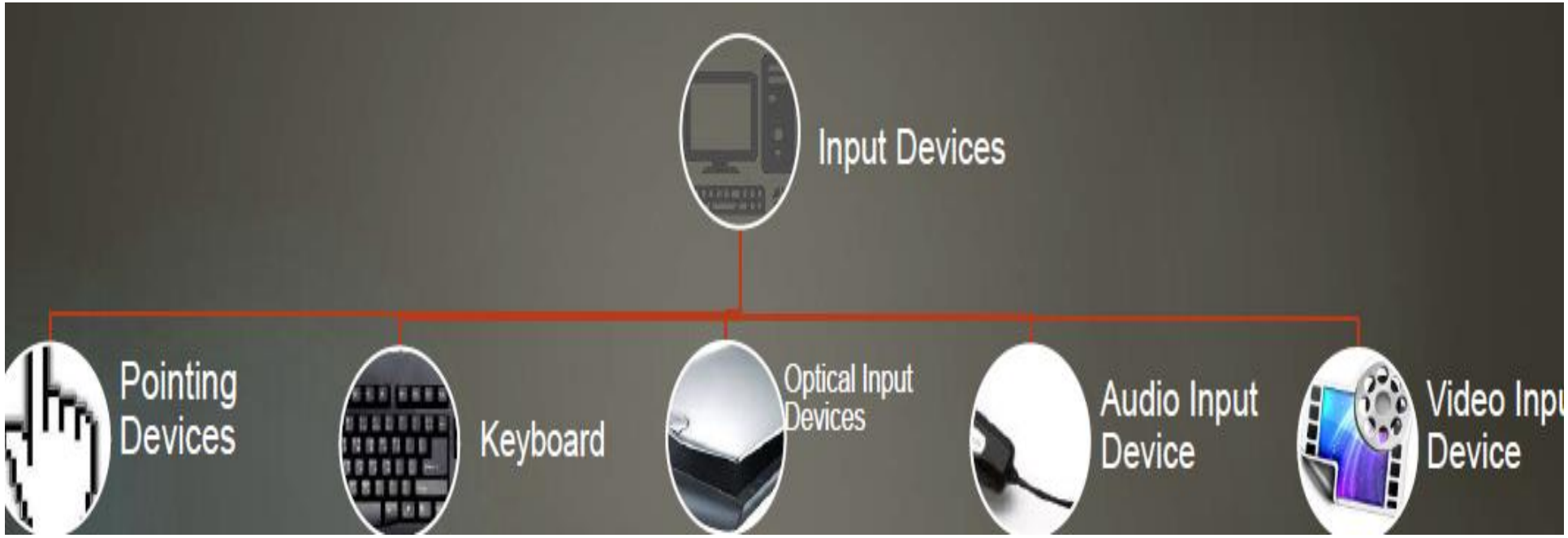
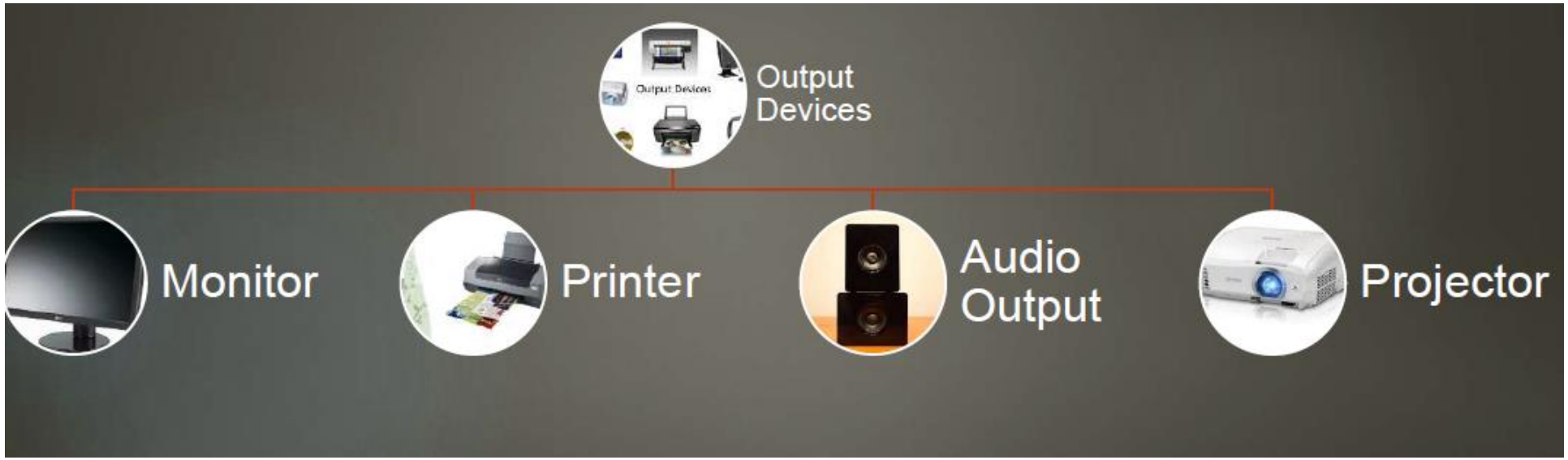


Output Devices

- Output Devices are used to receive information from the computer either in softcopy or hard Copy



Output Devices

•Monitor was invented in 1897 By **Karl Ferdinand Braun.**
•A **computer monitor or a computer display is** an electronic visual display for computers.
•A **computer monitor is an electronic device that shows** pictures for computers. Monitors often look similar to televisions.


Video Display Devices

- A video display device is an output device for presentation of information in visual way.
- When the input information is supplied as an electrical signal, the display is called an electronic display.
- Common applications for electronic visual displays are televisions or computer monitors.
- Different types of Video display devices are Cathode Ray Tube, Raster Scan displays, Random Scan displays, Color CRT-monitors, Direct View Storage Tube, Flat-Panel Displays, Light-emitting Diode(LED), Liquid-crystal Displays(LCDs).

Cathode Ray Tube (CRT)

- Invented by Karl Ferdinand Braun(1897).
- Convert electrical signals to visual signals.
- Beam of electrons directed from cathode(-) to phosphor-coated (fluorescent) screen (anode(+)).
- Directed by magnetic focusing and deflection coils(anodes) in vacuum filled tube.
- Phosphor emits photon of light, when hit by an electron, of varied persistence (long 15-20 ms for texts/short <1 ms for animation)
- Phosphors are organic compounds characterized by their persistence and their color (blue, red, green).

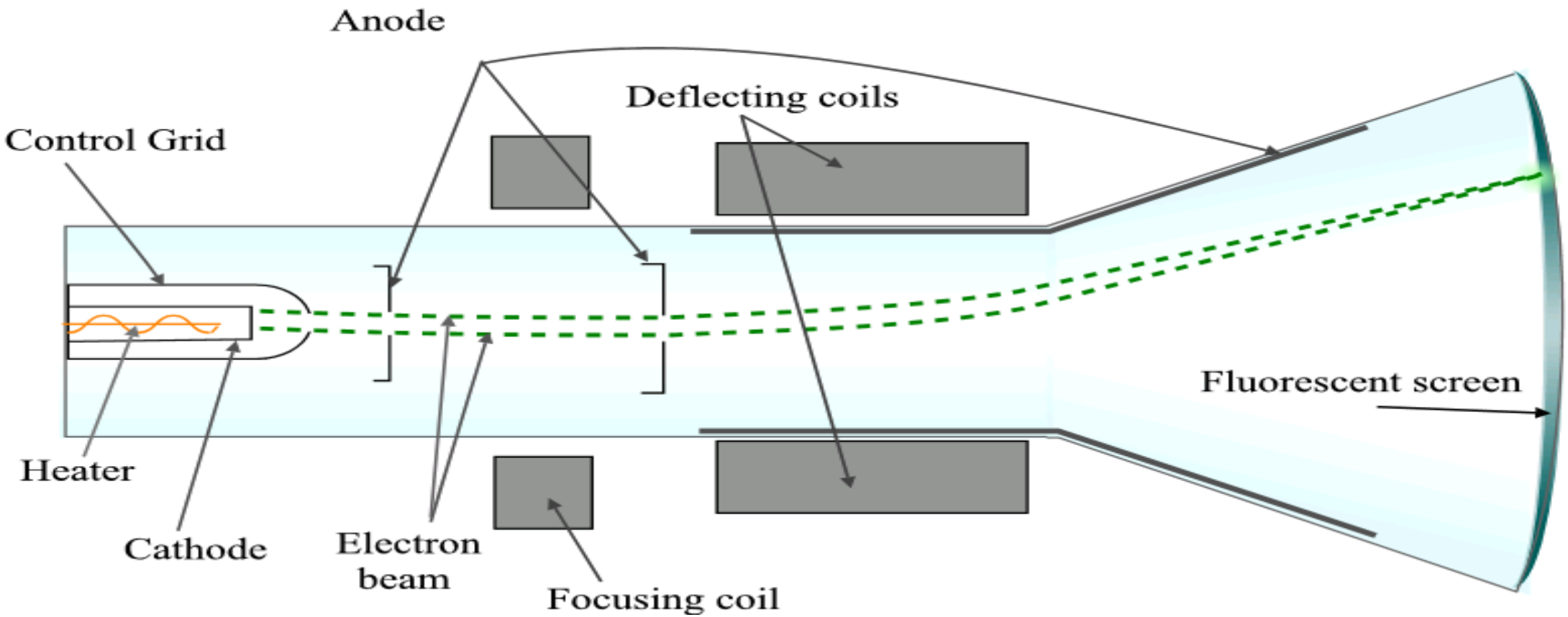
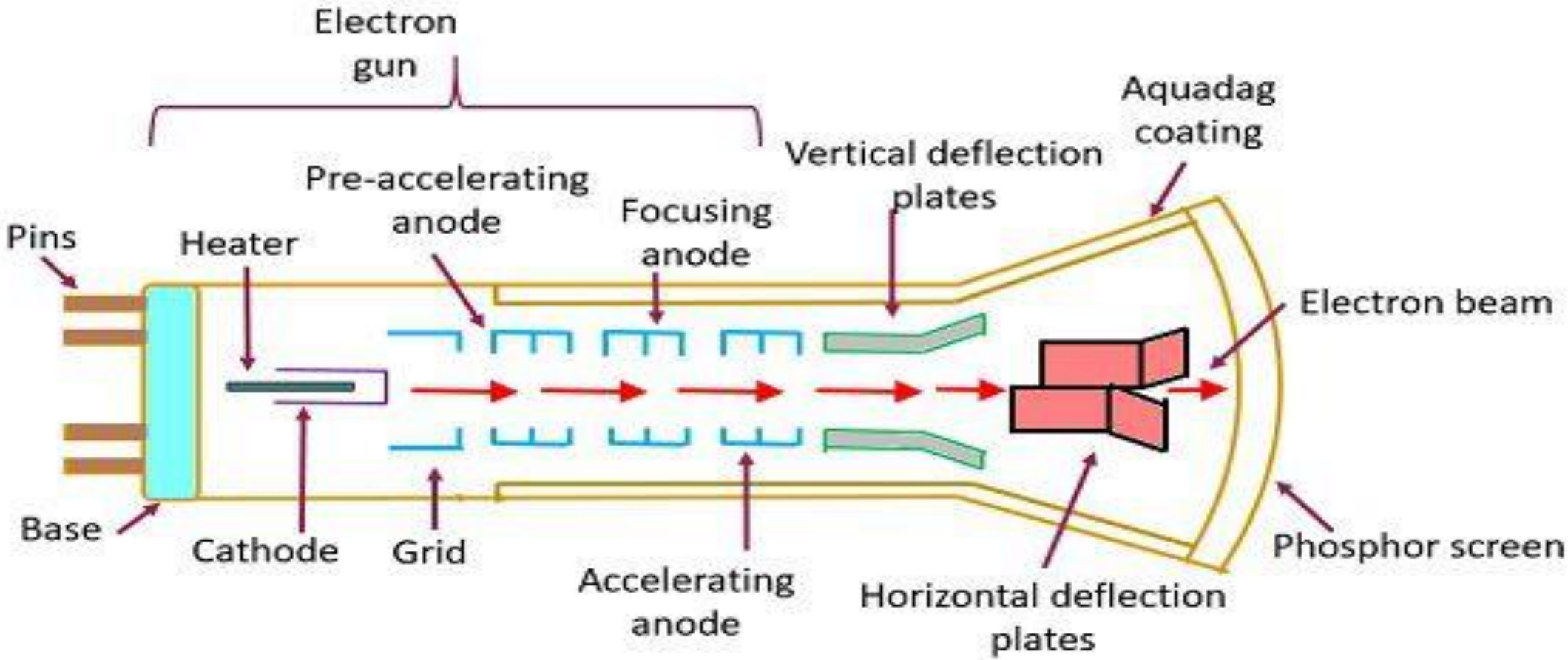


Figure : Cathode Ray Tube (CRT)



Internal structure of CRT

Electronics Coach

Characteristics of Cathode-Ray Tube (CRT)

- **Intensity:** It is proportional to the number of electrons repelled in beam per second (brightness).

- **Resolution:** It is the maximum number of points that can be displayed without overlap. It is expressed as number of horizontal points by number of vertical points. These points are called pixels (picture elements). Example: resolution 1024 x 768 pixels. Typical resolution is 1280 x 1024 pixels.
  - High-definition systems means high resolution systems.
  - Resolution of a CRT is dependent on the type of phosphor, the intensity to be displayed, and the focusing and the deflection systems.

- **Aspect Ratio:** It is the ratio of vertical points to horizontal points necessary to produce equal- length lines in both directions on the screen.
  - An aspect ratio of ¾ means that the vertical line plotted with three points has the same length as a horizontal line plotted with four points.

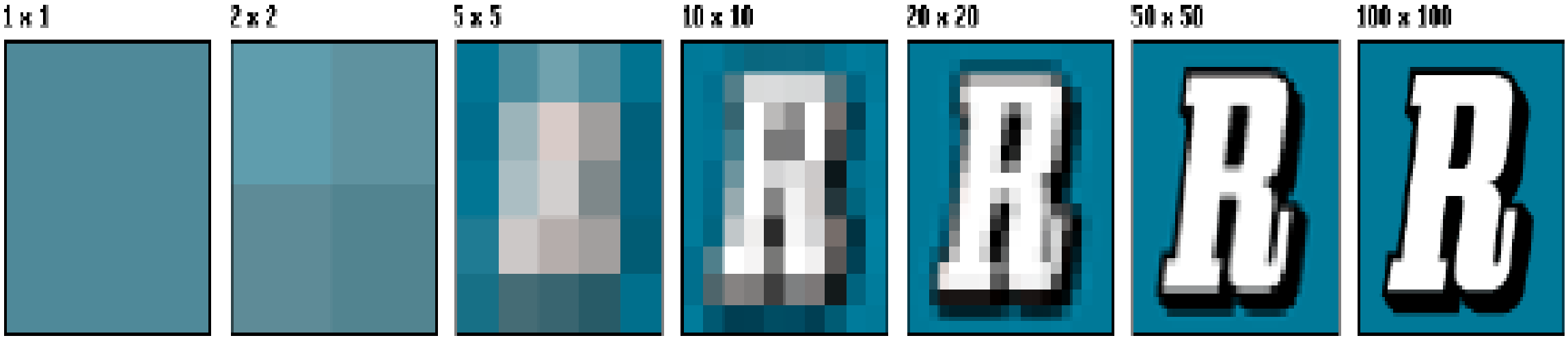


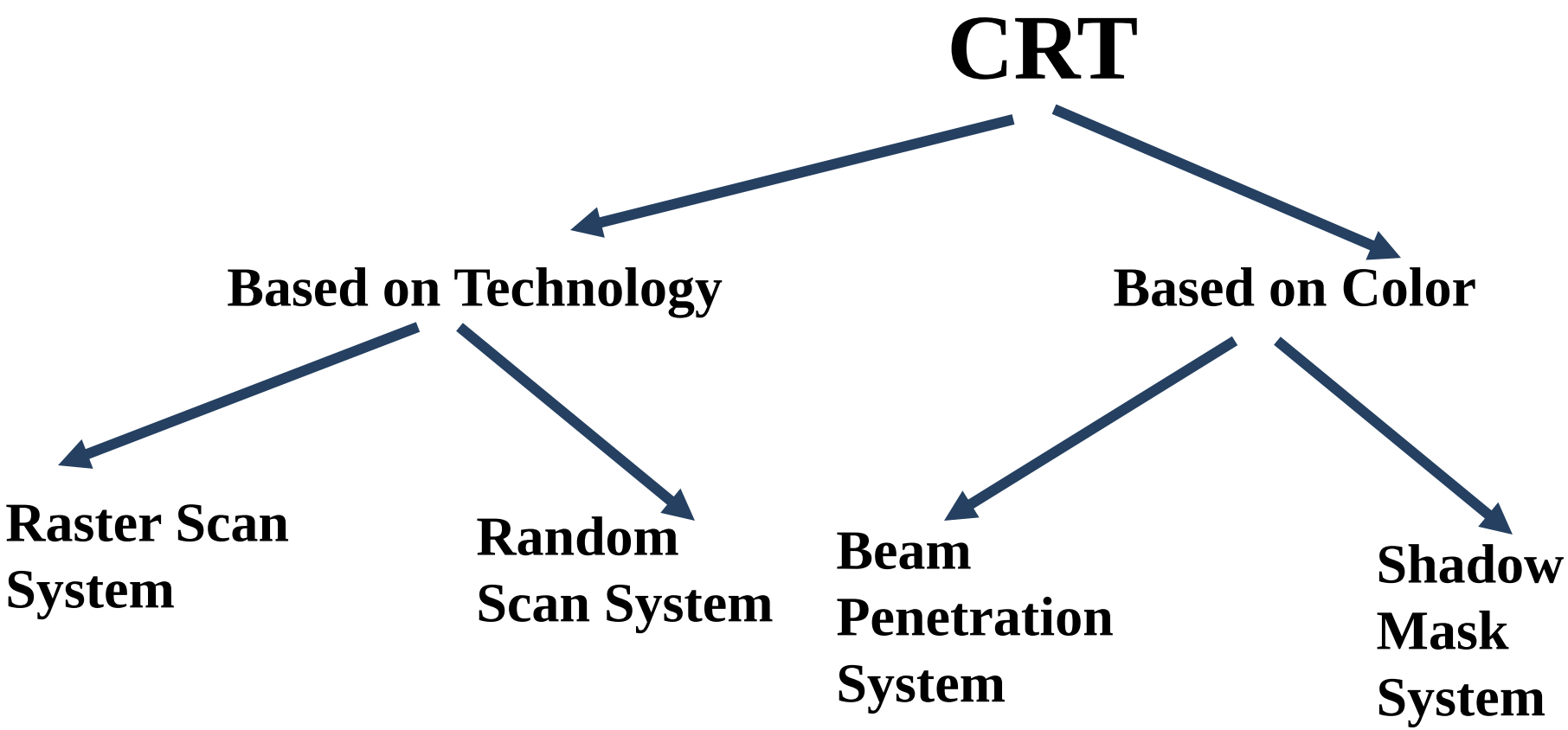
Figure : Resolution

Related Terms

Persistence: How long the phosphor continue to emit light after the CRT beam is removed.

- ✓ It is also defined as the time it takes the emitted light from the screen to decay to one-tenth of its original intensity.
- ✓ Low persistence phosphor requires higher refresh rates.
- ✓ Low persistence phosphor is useful for animation.
- ✓ High persistence phosphor is useful for displaying highly complex, static pictures

Categories of CRT



Brands of CRT

Figure : CRT Brands

Raster Scan System

- The electron beam is swept across the screen, one row at a time from top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.
- Each pixel on the screen can be made to glow with a different brightness.
- Color screen provide for the pixels to have different colors as well as brightness.
- Picture Definition is stored in a memory area called the **Refresh Buffer** or **Frame Buffer**.
- This memory area holds the set of intensity values for all the screen points.
- Stored intensity values are then retrieved from there fresh buffer and "painted“ on the screen one row (scan line) at a time as shown in figure in next slide.

Raster Scan System

- In raster scan approach, the viewing screen is divided into a large number of discrete phosphor picture elements, called pixels/dots.
- Pixel: One dot or picture element of the Raster.
- Scan Line: A row of pixels

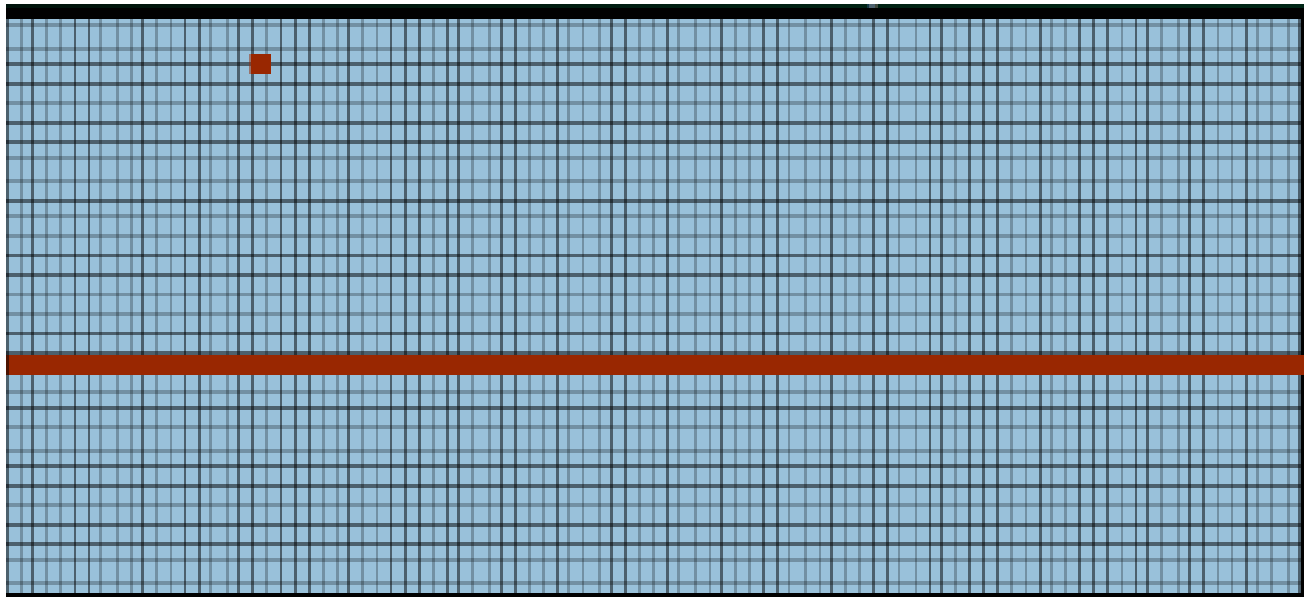


Figure : Example of Pixel

Raster Scan System

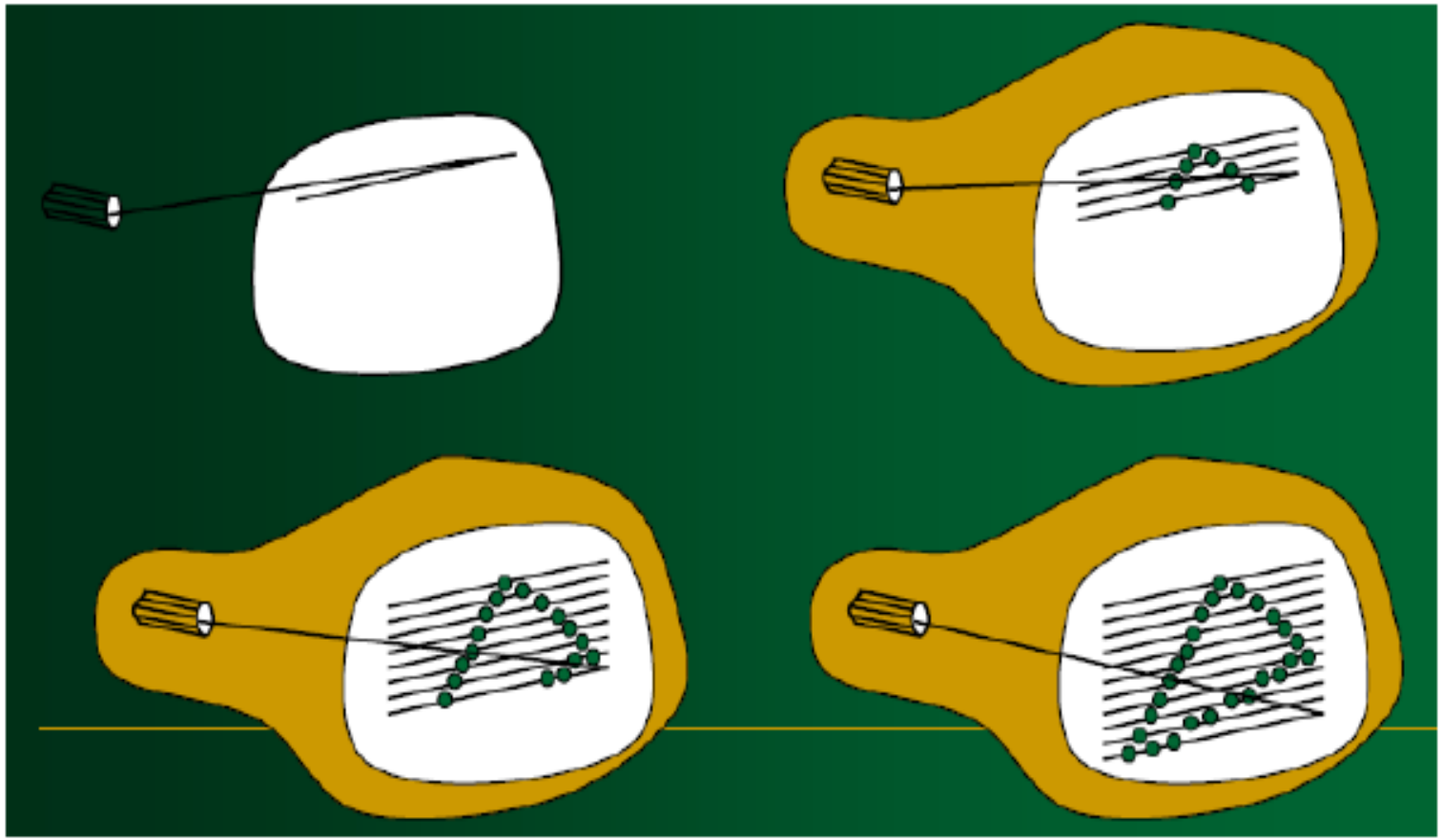


Figure : Image of Raster Scan System

Raster Scan System

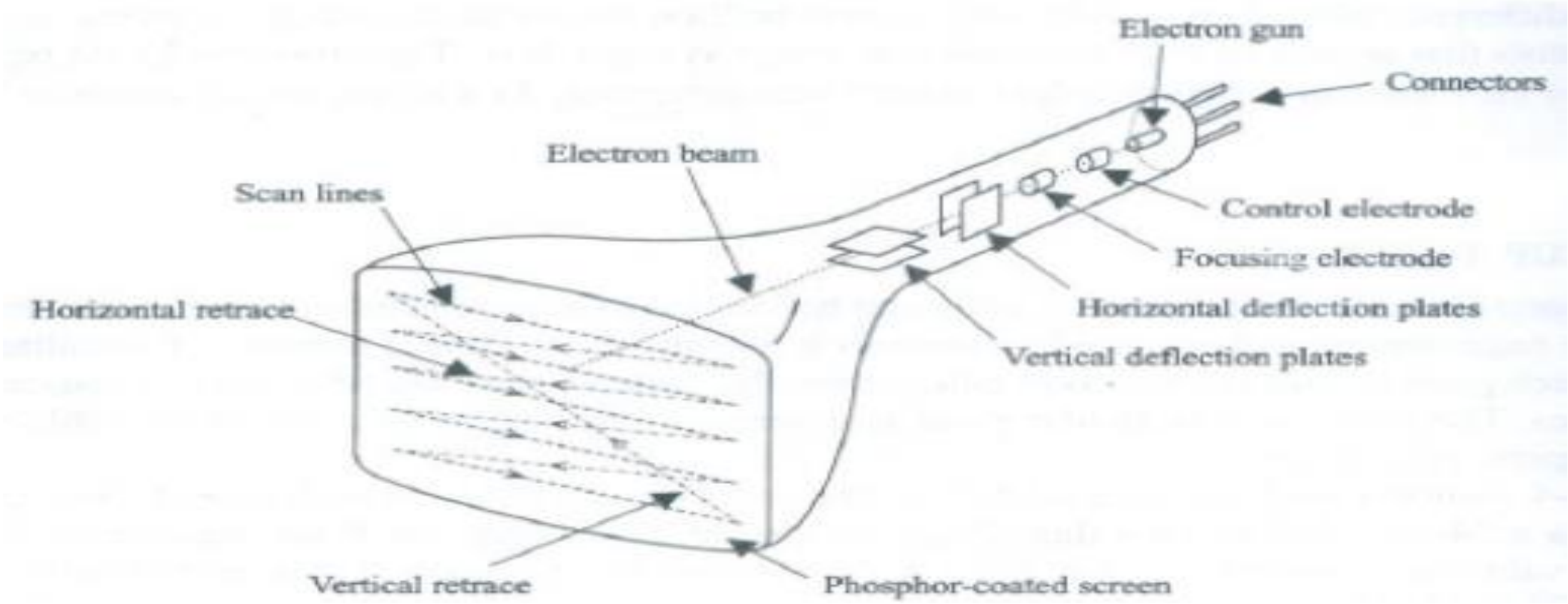
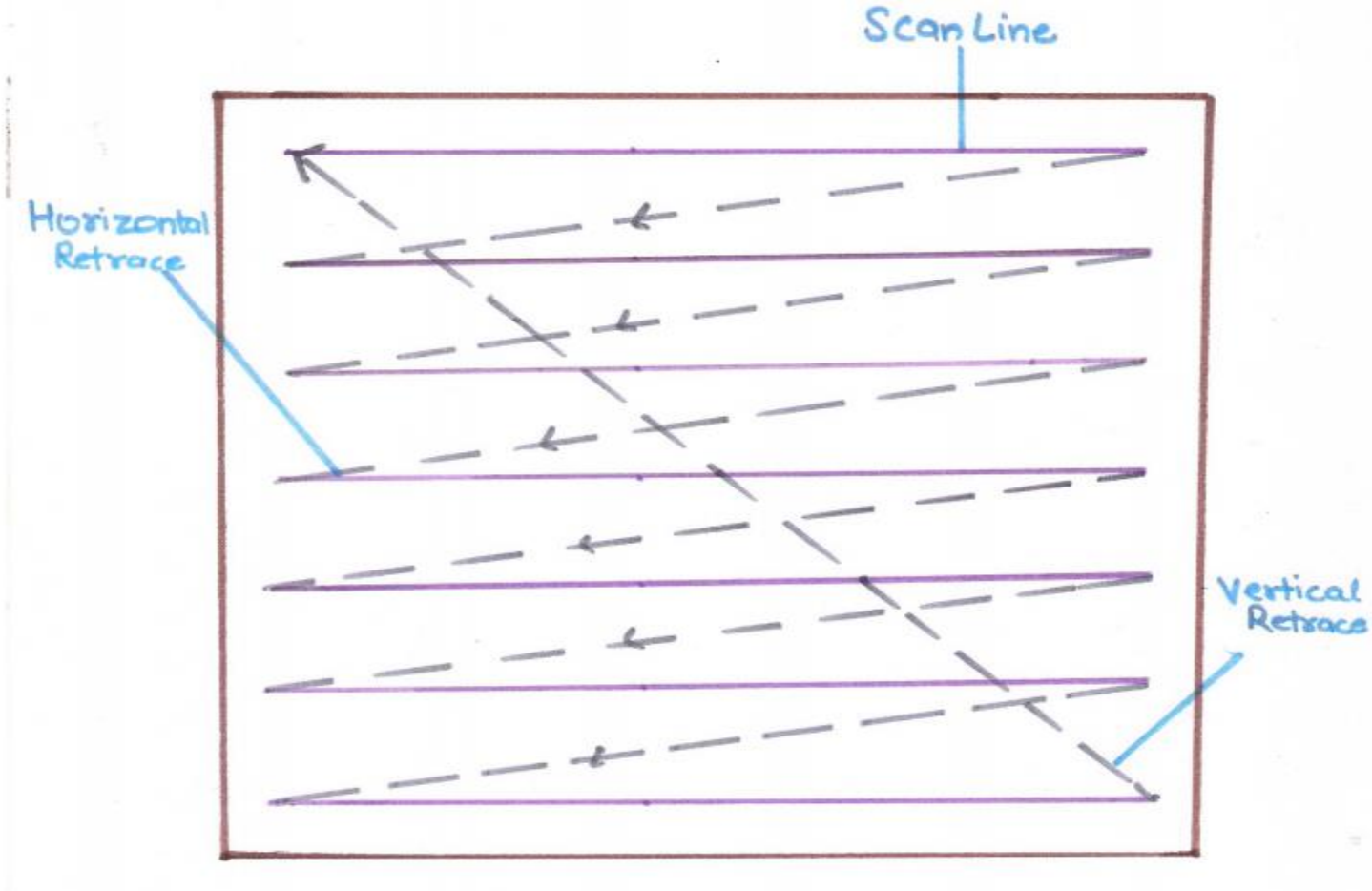


Figure : Image of Raster Scan System

- Intensity range for pixel positions depends on the capability of the raster system.
- In a simple black and white system, each screen point is either on or off, which makes the requirement of only 1 bit per pixel to control the intensity of screen positions.
- For a bilevel system, a bit value 1 indicates that the electron beam is to be turned on at that position and value 0 indicates the beam intensity is turned off.
- Additional bits are needed when color and intensity variations can be displayed.

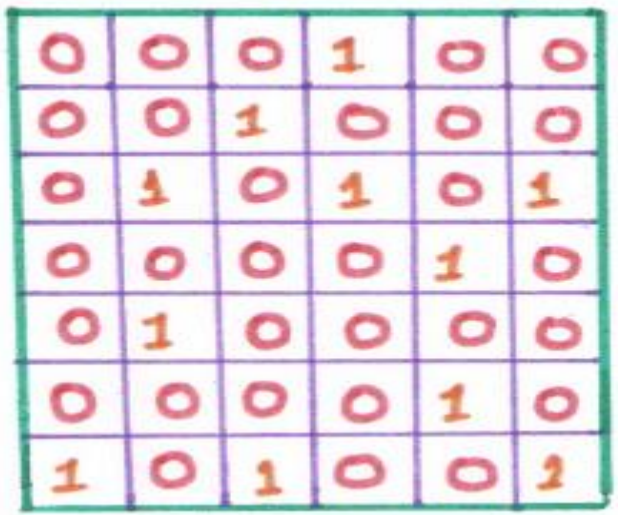
- On a black and white system with one bit per pixel, the frame buffer is called a bitmap.
- For a systems with multiple bits per pixel, the frame buffer is referred to as pixmap.

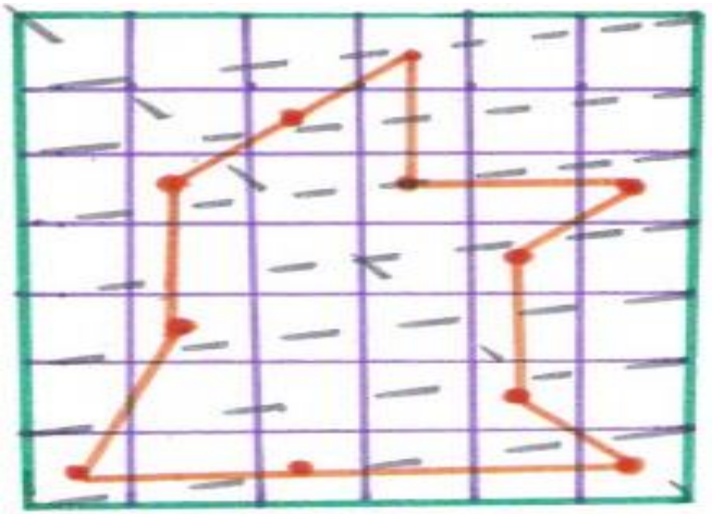
Raster Scan System



- Refreshing on raster-scan displays is carried out at the rate of 60 to 80 frames per second.
- Refresh rates are described in units of cycles per second or or Hertz, where cycle corresponds to one frame.
- At end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line. The return to the left of the screen, after refreshing each scan line is called the **horizontal retrace** of the electron beam.
- At the end of each frame, the electron beam returns to the top left corner of the screen to begin the next frame is called **vertical retrace**.

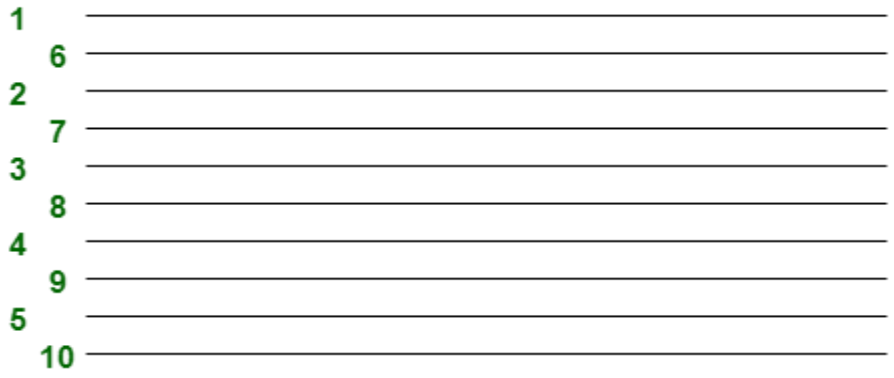
Raster Scan System





Interlacing

- When referring to a computer monitor or another display, **interlace** or **interlacing** is a description of how the picture is created. With an interlaced display the picture is created by scanning every other line, and on the next scan, scanning every opposite line. Interlacing allows for a faster refresh rate by having less information during each scan at a lower cost. Unfortunately, this may cause flickering or noticeable line movements in some situations.



Interlaced Scan

Raster Scan System

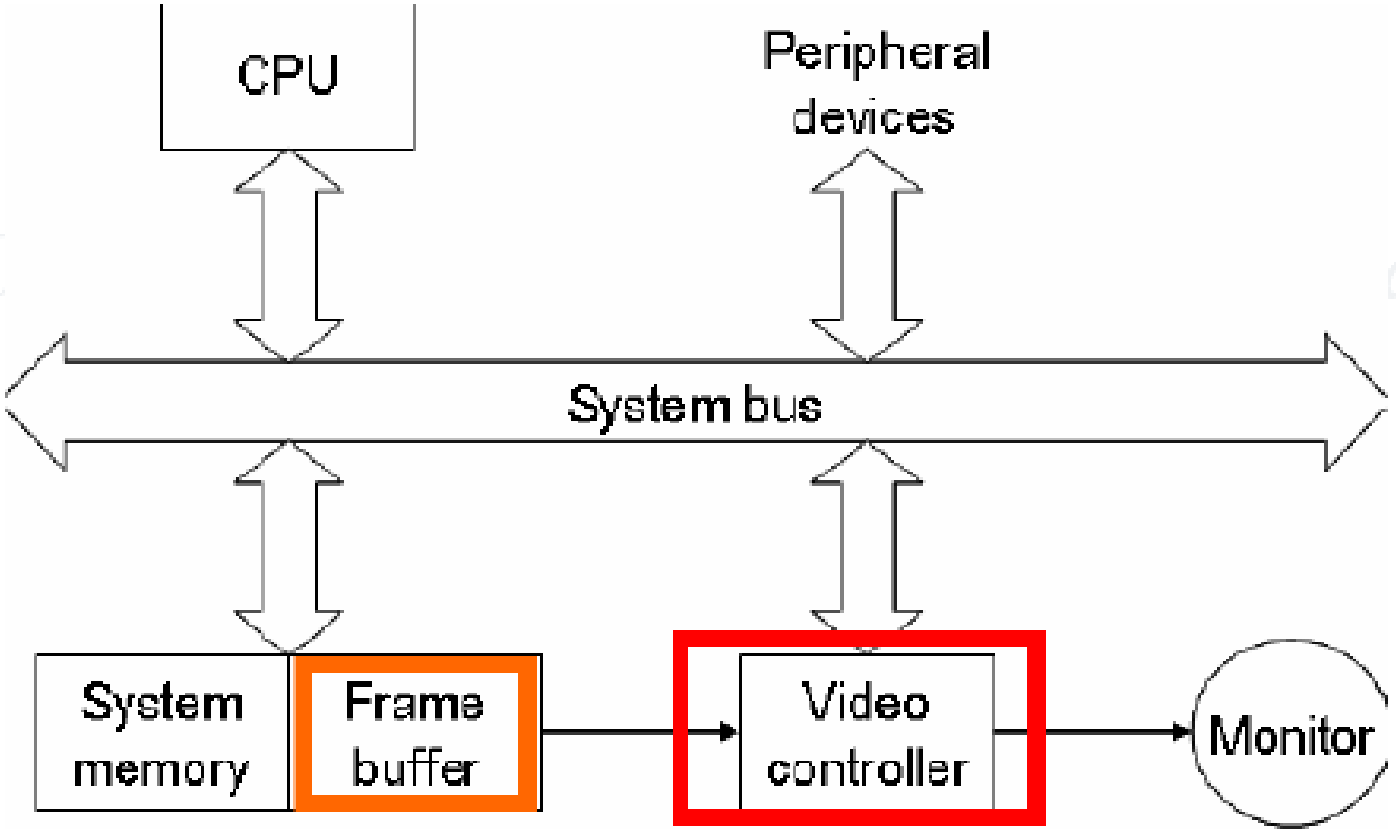
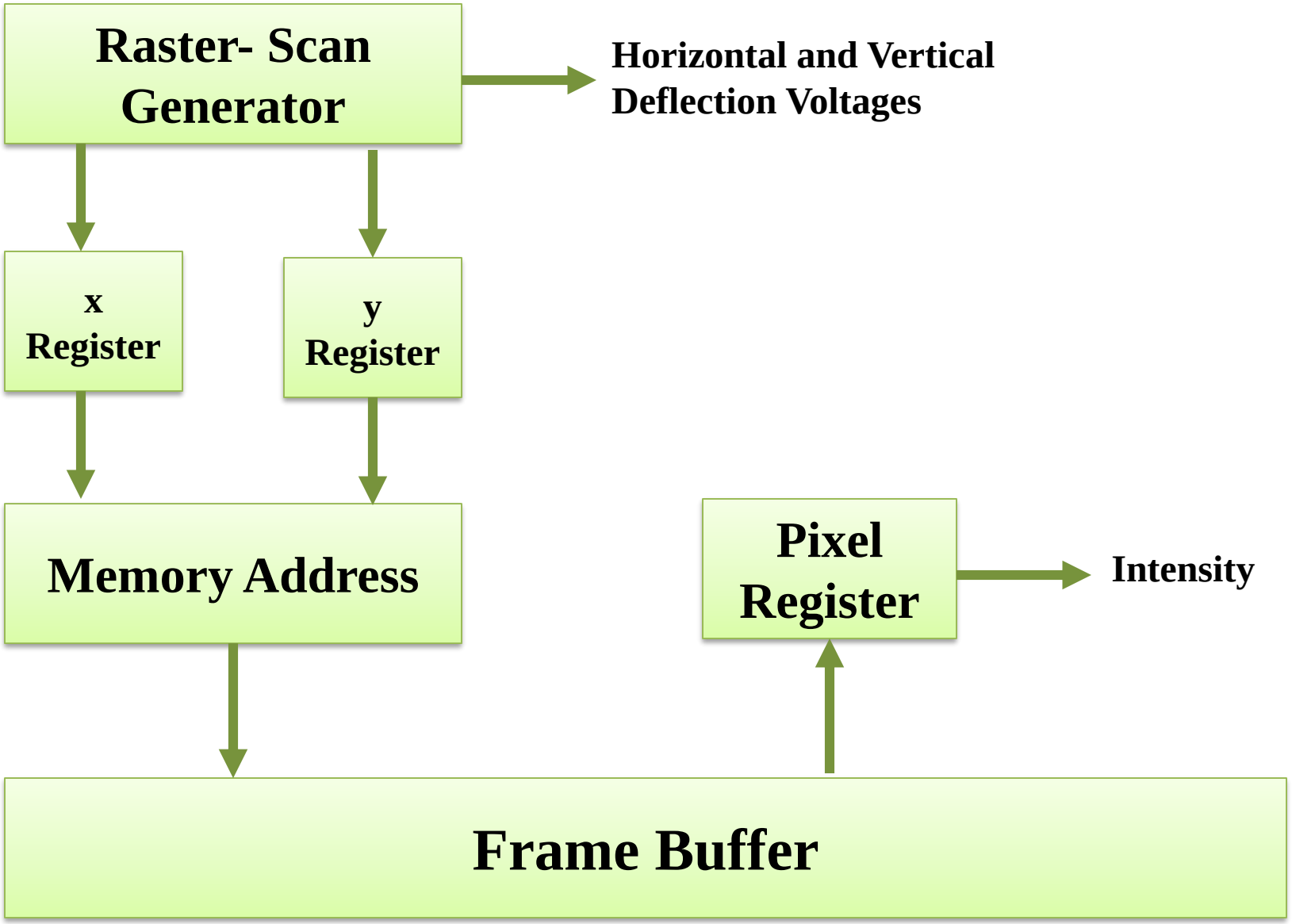


Figure : Raster Scan System's Architecture

Raster Scan System

- In addition to the Central Processing Unit (CPU), a special processor, called the Video Controller or Display Controller, is used to control the operation of the Display Device.
- A fixed area of the system memory is reserved for the frame buffer, and the video controller is given direct access to the frame buffer memory.
- Frame buffer locations and the corresponding screen positions are referenced in Cartesian coordinates.
- The coordinate origin is defined at the lower left screen corner.
- The screen surface is represented as the first quadrant of a 2D system, with positive x values increasing to the right and positive y values increasing from bottom to top.
- Scan lines are labeled from y_{max} at the top of the screen to 0 at the bottom.
- Along each scan line, screen pixel positions are labeled from 0 to x_{max}.

Basic Refresh Operation of the Video Controller



Raster Scan System

❑ Other Operations performed by Video Controller are:

- It can retrieve pixel intensities from different memory areas on different cycles
- In high quality systems, two frame buffers are often provided so that one buffer can be used for refreshing and other filled with intensity values. Provide the fast mechanism for generating real time animation.
- Video controllers often contain a lookup table, so that pixel value in the frame buffer are used to access the lookup table instead of controlling the CRT beam intensity directly.

Random Scan System

- When operated as a random-scan display unit, a CRT has the electron beam directed 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/stroke-writing/calligraphic displays.

Random Scan System

- 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**.
- Random scan systems are designed for line drawing applications and can not display realistic shaded scenes.
- Since picture definition is stored as a set of line drawing instructions and not as a set of intensity values for all screen points, vector displays generally have higher resolution than raster systems.

Random Scan System

The component lines of a picture can be drawn and refreshed.

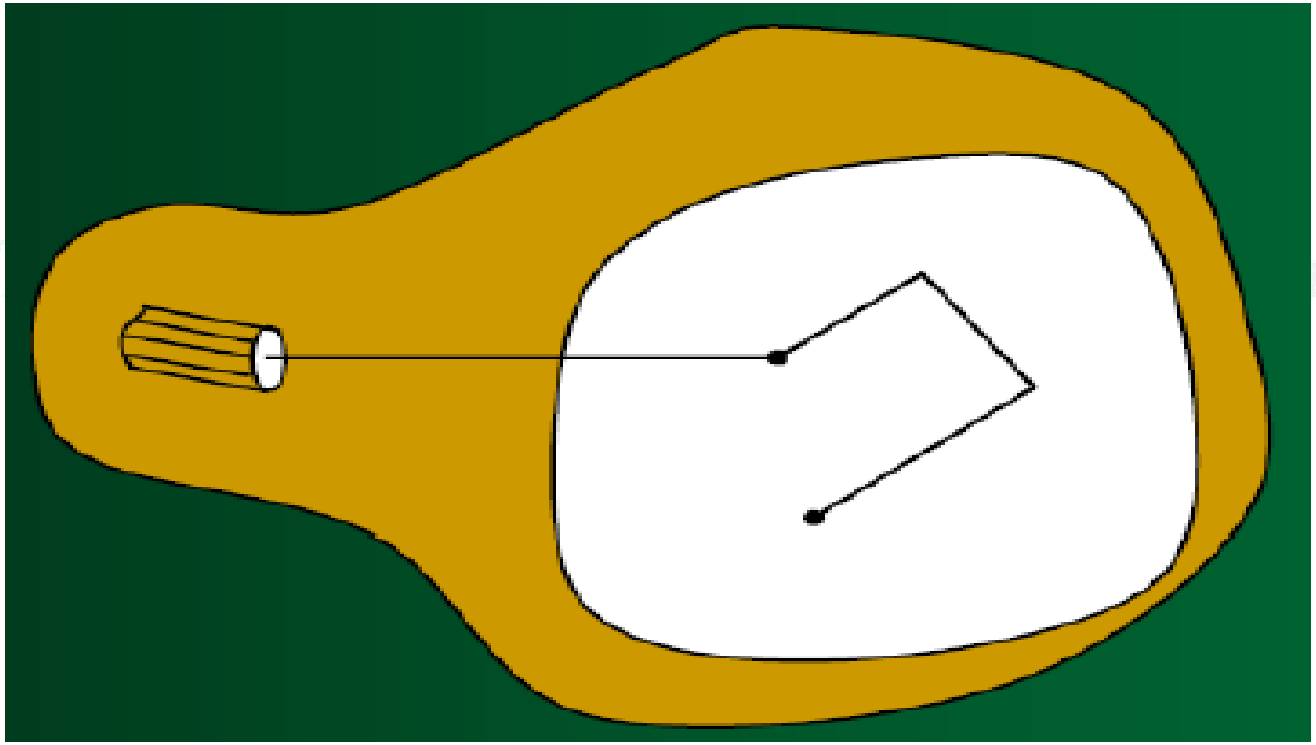


Figure 6: Random Scan System

Random Scan System

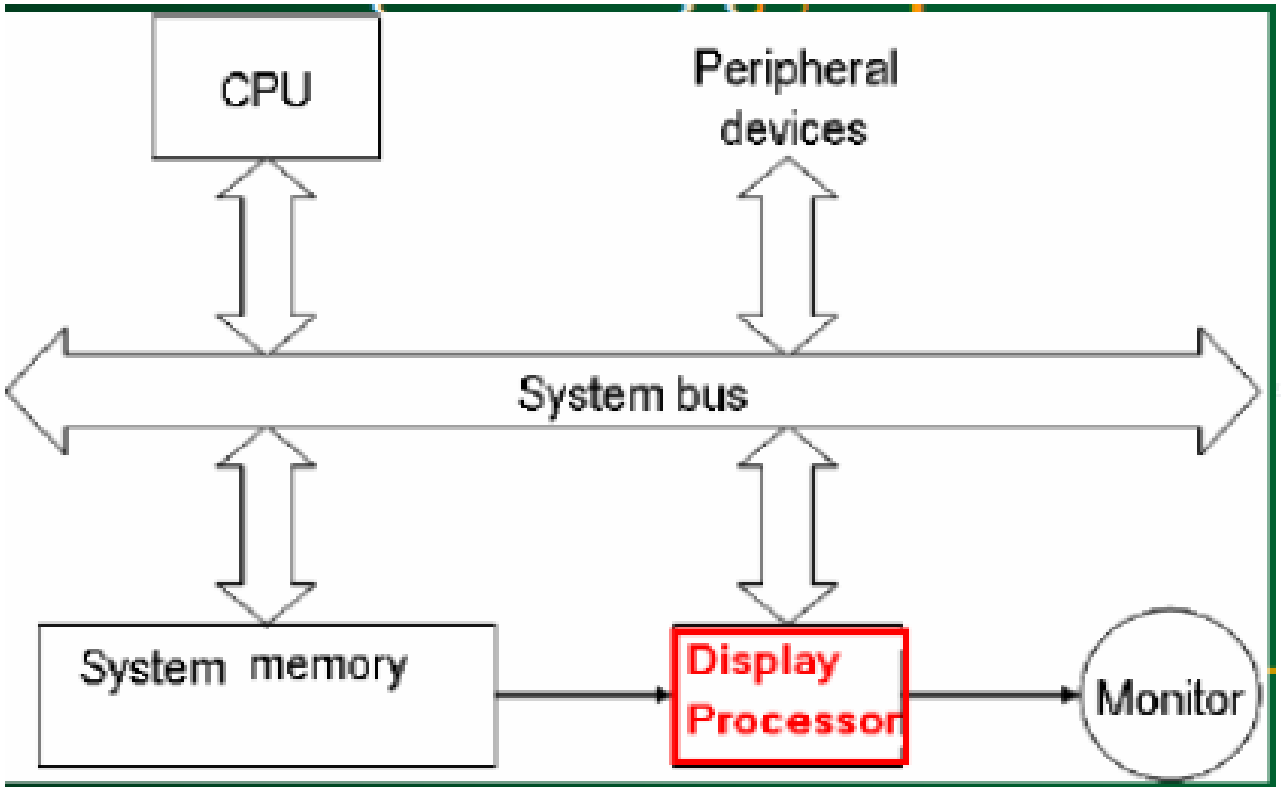


Figure : Random Scan System's Architecture

- An application program is input and stored in the system memory along with a graphics package.
- Graphics commands in the application program are translated by the graphics package into a display file 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.
- The display processor is also referred to as a display processing unit or a graphics controller.
- Graphics patterns are drawn on a random-scan system by directing the electron beam along the component lines of the picture.

Random Scan System

Random Scan Displays are designed to draw all the component lines of a picture 30 to 60 times each second.

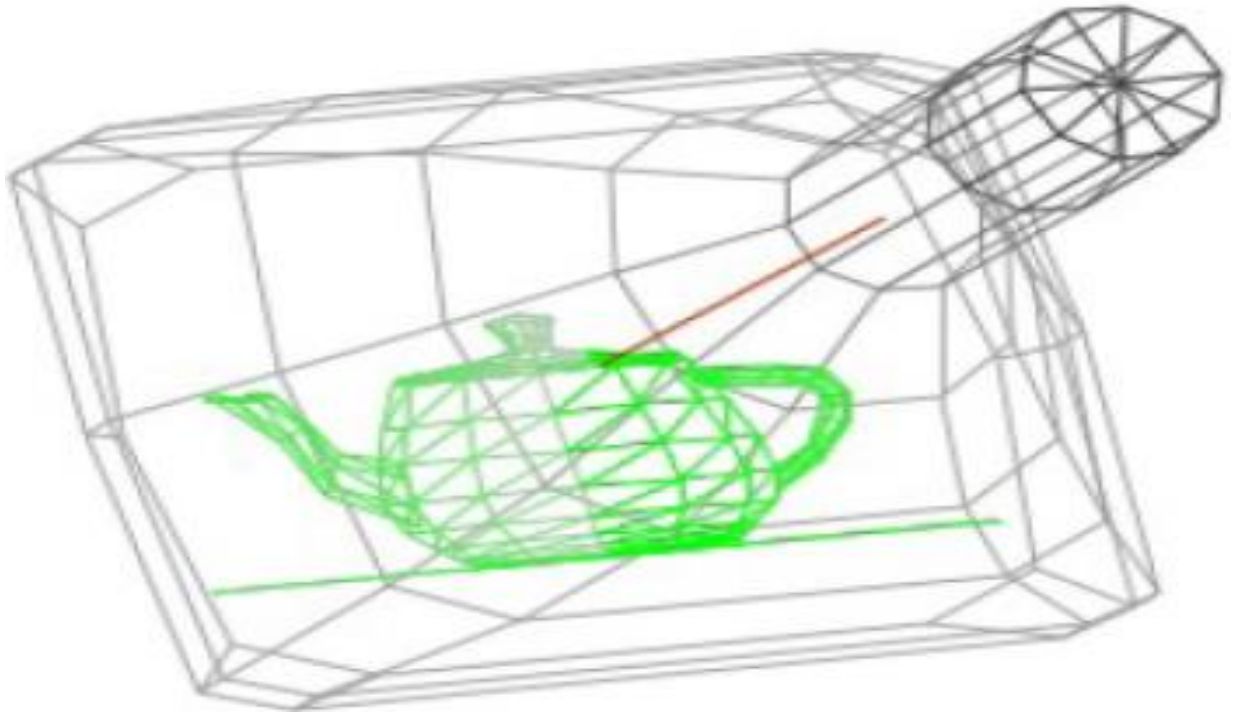


Figure : Random Scan System's Display

Raster v/s Random Scan System

Difference	Raster Scan System	Random Scan System
Resolution	It has poor **or less Resolution** because picture definition is stored as a intensity value.	It has **High Resolution** because it stores picture definition as a set of line commands.
Electron Beam	It is directed from top to bottom and one row at a time on screen, but electron beam is directed to whole screen.	It is directed to only that part of screen where picture is required to be drawn, one line at a time so also called Vector Display.
Cost	It is **less expensive**	It is **Costlier** than Raster Scan System.
Refresh Rate	Refresh rate is 60 to 80 frame per second.	Refresh Rate depends on the number of lines to be displayed i.e 30 to 60/sec

Raster v/s Random Scan System

Difference	Raster Scan System	Random Scan System
Picture Definition	It stores picture definition in **Refresh Buffer** also called **Frame Buffer**.	It stores picture definition as a set of line commands called **Refresh Display File**.
Line Drawing	**Zig–Zag line** is produced because plotted value are discrete.	**Smooth line** is produced because directly the line path is followed by electron beam
Realism in Display	It contains shadow, advance shading and hidden surface technique so gives the **realistic display** of scenes.	It does not contain shadow and hidden surface technique so it **can not** give **realistic display** of scenes.
Image Drawing	It uses **Pixels** along scan lines for drawing an image.	It is designed for **line drawing applications** and uses various mathematical function to draw.

Raster v/s Random Scan System

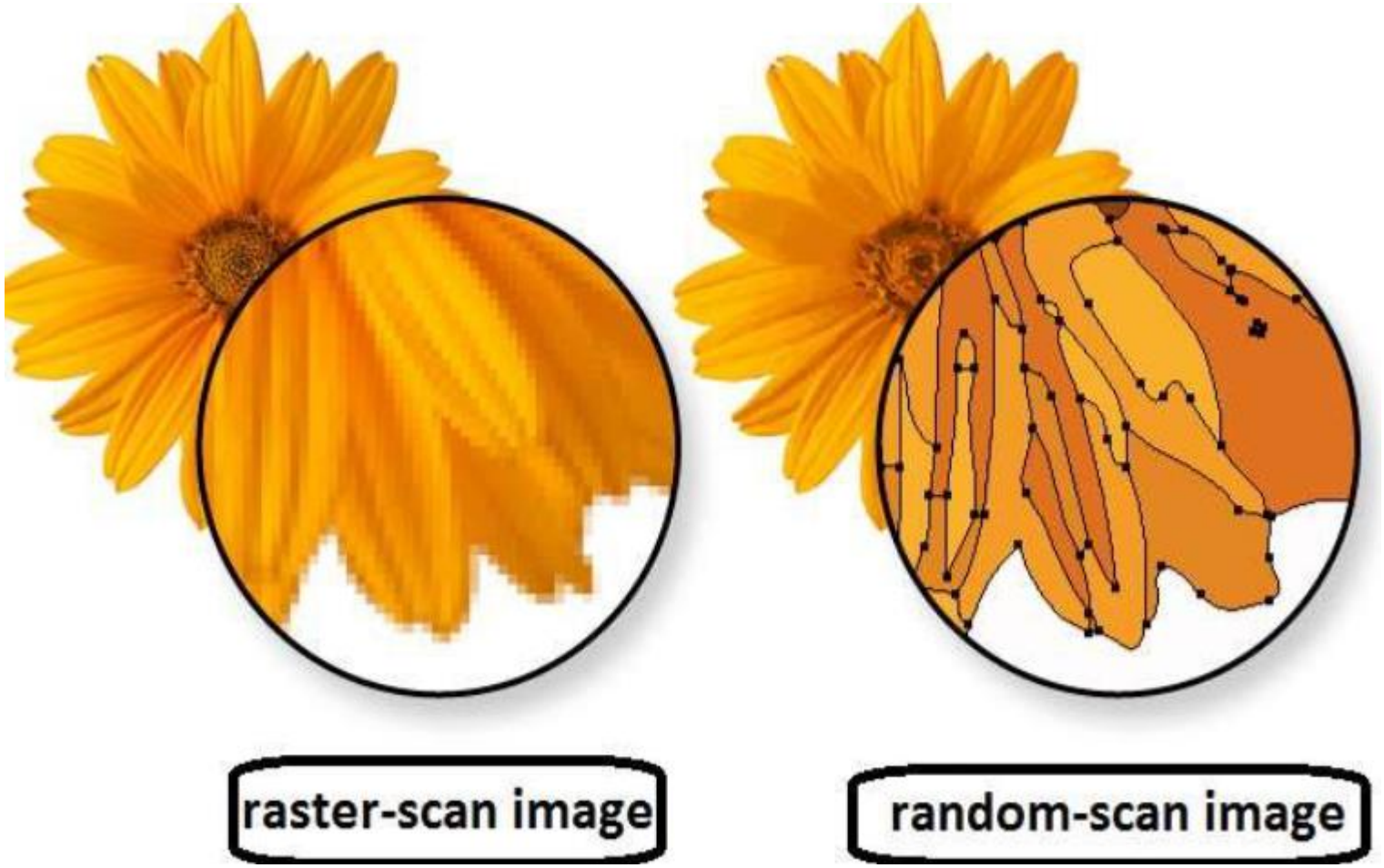


Figure : Raster v/s Random Scan image

Additional online materials

- http://www.accad.ohiostate.edu/~waynec/history/timeline.html
- Coursera- https://www.coursera.org/learn/fundamentals-of-graphic-design
- https://www.youtube.com/watch?v=fwzYuhduME4&list=PLE4D97E3B8DB8A590
- NPTEL - https://nptel.ac.in/courses/106/106/106106090/
- https://www.coursera.org/browse/physical-science-and-engineering/research-methods