# Computer Graphics

## CHAPTER - 1
## INTRODUCTION

# Outline



- What is Computer Graphics?
- Components of Computer Graphics
- Application Areas of Computer Graphics
- Graphical Display Devices
- Graphical Input Devices
- Software Standards – Open GL, GKS, PHIGS

# What is Computer Graphics?



- **Computer graphics** generally means ***creation, storage* and *manipulation*** of *models* and *images*.
- *It is an art of* ***drawing pictures****, lines, charts etc. on* ***computer screen*** *by using programming language*.
- Computer graphics is the process of **creating an object into a computer.**
  - Using a computer as a **rendering tool** for the generation **(from models)** and manipulation of images is called **computer graphics.**
- It is about how to program a **computer to generate photo-realistic** images.
  - Technically, it's about the **production, *manipulation* and *display* of images** using computers; and
  - Practically, it's about **movies, games, art, training, advertising, communication, design,** etc.
- The term computer Graphics describes any use of computers to create or manipulate images.

# What is Computer Graphics?



- **Computer graphics** deals with the generation of **pictures, designs,** etc. on a computer.
- The aim of **computer graphics** is to produce **realistic and/or useful** images on a computer.
- For some applications the emphasis will be on **realism** (e.g. special effects in films), whereas for others it will simply be on **usefulness** (e.g. **data visualisation**).
- **Computer graphics** is a use of computer to define, store, manipulate and produce pictorial output.
- It is a branch of **computer science** that deals with the **theory and technology** for computerized image synthesis.
- It refers to the creation, storage and manipulation of pictures and drawings using a digital computer.
- Generally ***Computer graphics*** deals with **graphics** created using computers and the representation of **image data** by a computer specifically with help from specialized graphic **hardware and software.**

# Components of Computer Graphics



- Computer graphics deals with all aspects of creating **images with a computer** – *Hardware*, *Software* and *Applications*.
- **Modeling:**
  - Modeling refers to the process of defining objects in terms of **primitives, coordinates and characteristics and creating** and representing the **geometry** of objects in the **3D world.**
- **Storing:**
  - Storing scenes and images in **memory and on disk.**
- **Manipulating:**
  - The process of **changing the *shape*, *position* and *characteristics*** of objects in a scene.

# Cont….



- **Rendering:**
  - The process of applying physically based procedures to generate (**photorealistic**) images from scenes (using **lighting** and **shading**).
- **Viewing:**
  - The process of displaying images from various viewpoints on various devices.
- **Animation:**
  - (movement) describing how objects change in time.

# Why study computer graphics?



- "A picture is worth than a **thousand words**"

→ Communication using **picture** (charts, diagrams, graphs etc) is easy.

→ **Data volume** (to store large data). A **huge database** can be presented by **pictures.**

→ **Time (it saves time).** Since large database can be presented using pictures, time to review these is minimum compared to **reviewing** the whole **database** in **textual forms**.

# Why study computer graphics?



- Graphics is cool
  - I like to see what I'm doing and to show people what I'm doing
  - Enable scientists (also engineers, physicians, and general users) to observe their **simulation and computation**.
  - Enable them to describe, explore, and summarize their datasets (models) and gain insights Enrich the discovery **process and facilitate new inventions.**
  - Enrich the discovery process and facilitate **new inventions**
- Graphics is interesting
  - Involves *simulation*, AI, *algorithms*, *architecture*…
- Graphics is fun
- Almost no area in which **graphical displays cannot** be used

# Cont…

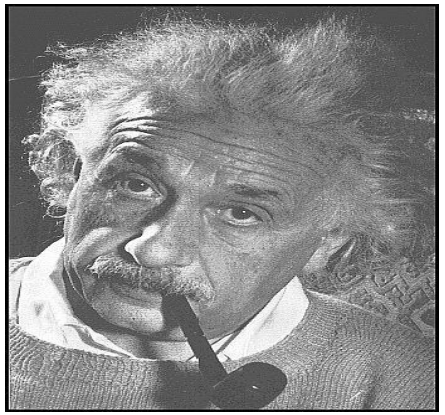


Many of the leading scientists through the ages have been ‘visual thinkers’…

-Leonardo da Vinci

-Einstein

-Clerk Maxwell



**Why Visualization**

- Analyze and communicate information
- Revolutionize the way scientists/engineers/physicians
- conduct research and advance technologies
- About 50% of the brain neurons are associated with **vision**

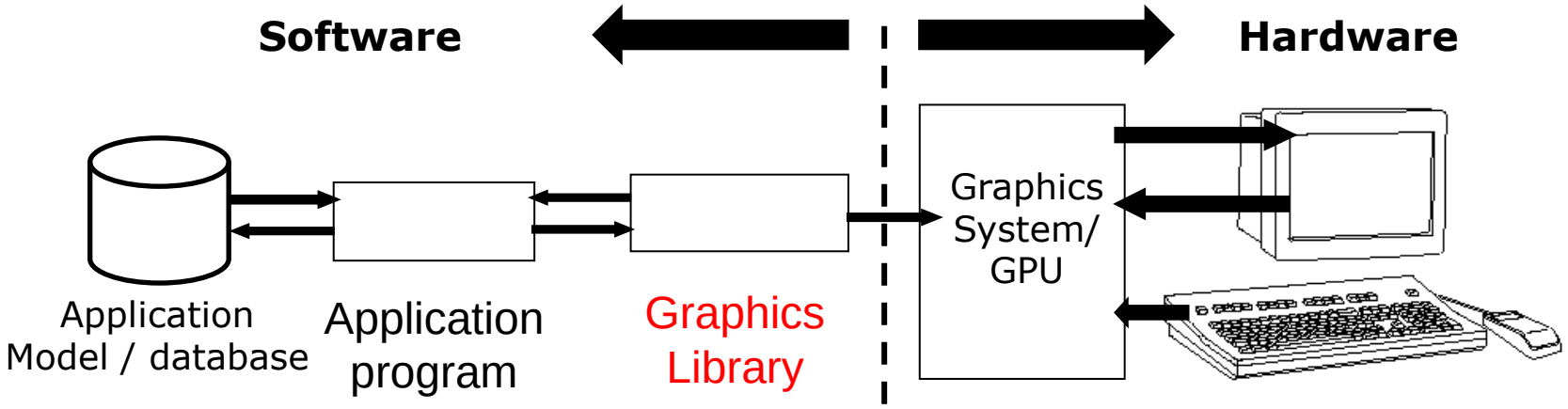
# Categories Computer Graphics?



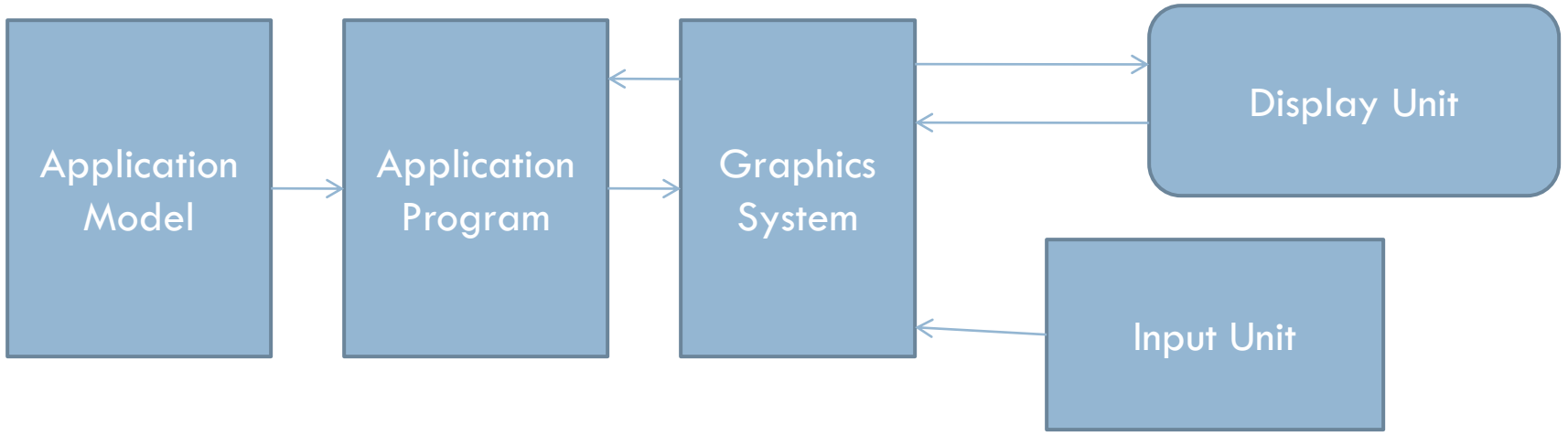
- **Interactive Graphics**
  - In interactive **computer graphics** user have some control over the picture i.e. user can make any change in the **produced image**.
- **Passive Graphics**
  - A computer graphics operation that transfers **automatically** and **without operator intervention.**
  - Non-interactive computer graphics involves one way communication between the computer and the user.

# Conceptual Framework for Interactive Graphics

- Graphics library/package is **intermediate** between application and display hardware (Graphics System)
- Application program maps application objects to views (images) of those objects by calling on **graphics library**. Application model may contain lots of **non-graphical data** (e.g., non-geometric object properties)
- User interaction results in modification of **image and/or model**
- This hardware and software framework is **5 decades old** but is still useful



# Interactive Graphics system




- Designer of **computer graphics system** or **software engineer** puts his design in application model.
- He/she will then writes the program to model the object he is planning to display.
- This application will run on the **computer graphics system and output** will be displayed on the display devices and the required input can be obtained from the **input devices**.

# Application Areas of Computer Graphics

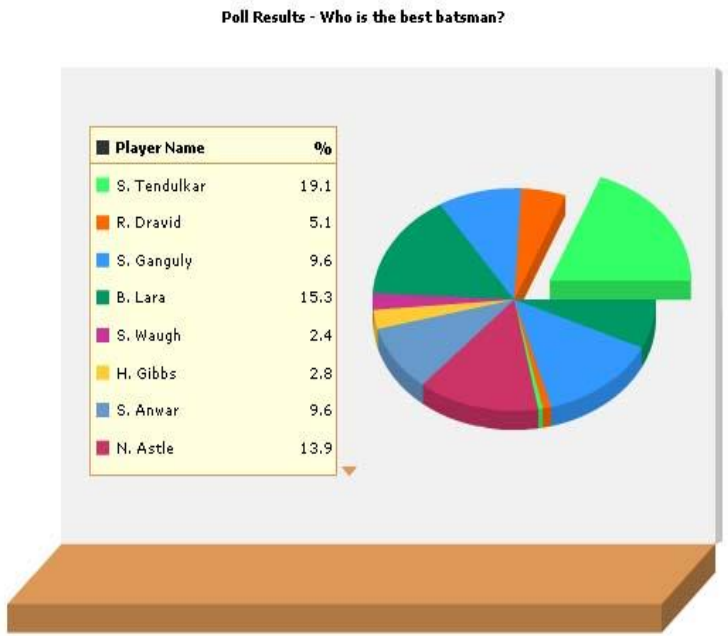


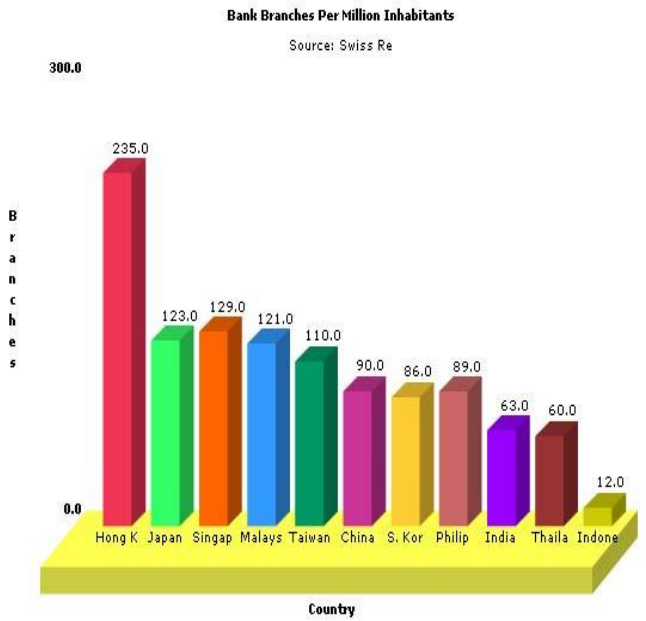
- Presentation Graphics
- Computer Aided Design(CAD)
- Visualization
- Computer Art
- Education and training
- Image processing
- Entertainment
  - Movies Industry
  - Gaming Industry
- Medical field
- Graphical User Interface(GUI)
- Virtual Reality and Augmented Reality

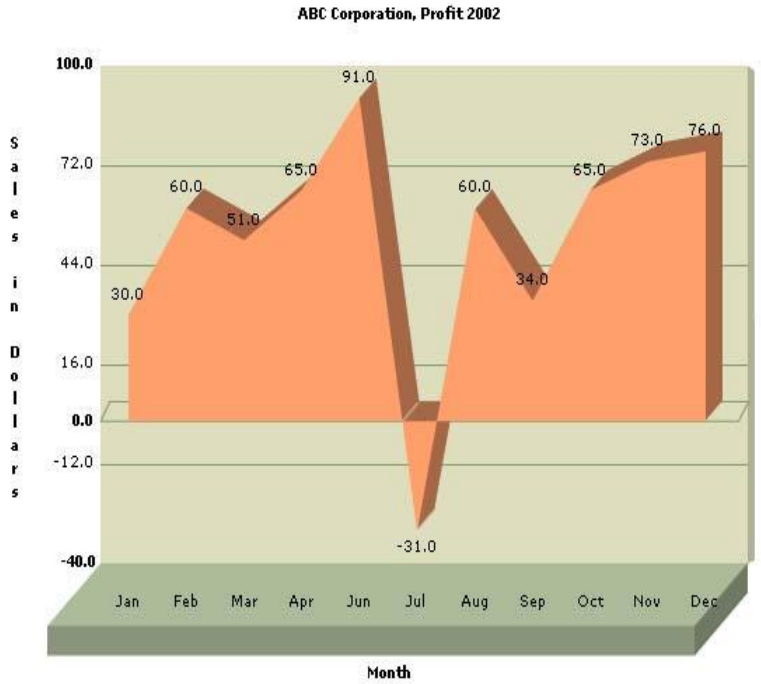
# Application Areas of Computer Graphics "Presentation Graphics"



- Used to summarize the *financial*, *mathematical*, *scientific* and *economic* data.
  - Typical examples are **bar charts, line graphs, pie charts** etc.



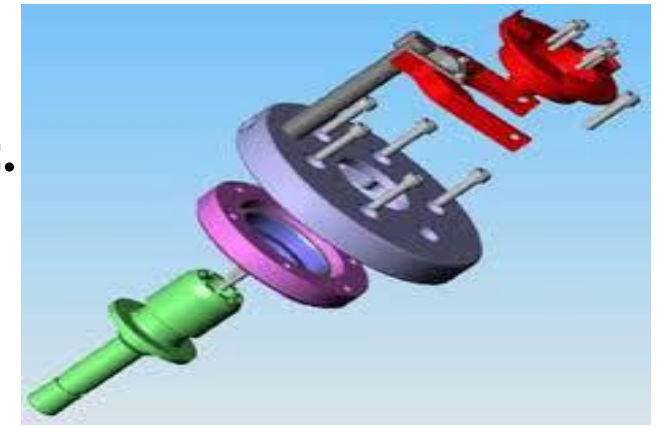



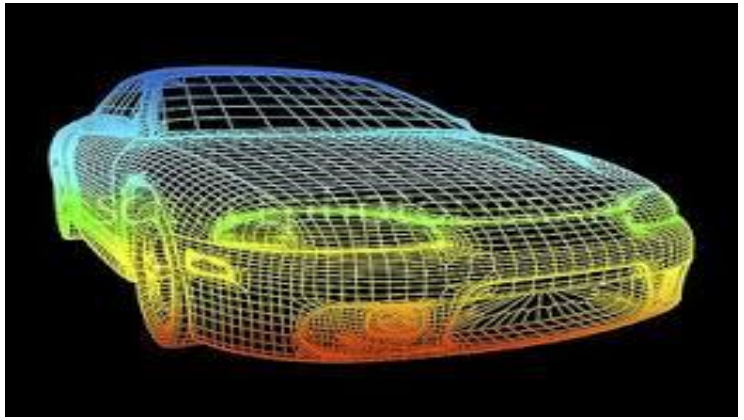



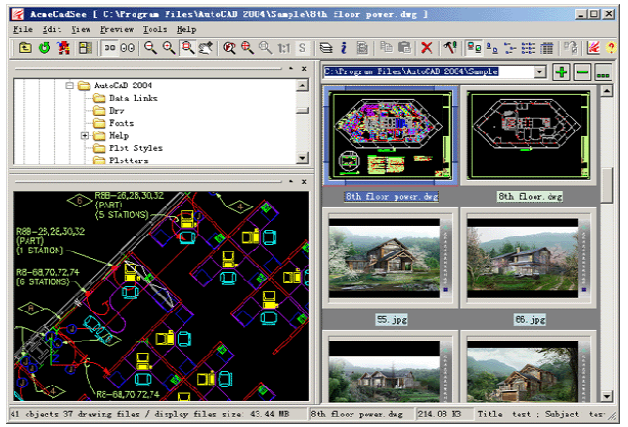
# Application Areas of Computer Graphics "Computer Aided Design(CAD)"

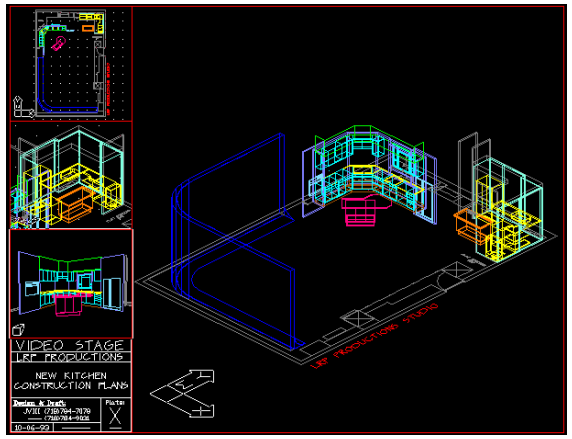


- Major use of computer graphics is in design process, particularly for engineering and architectural systems.
  - This include design of **buildings, automobiles, aircraft** etc.





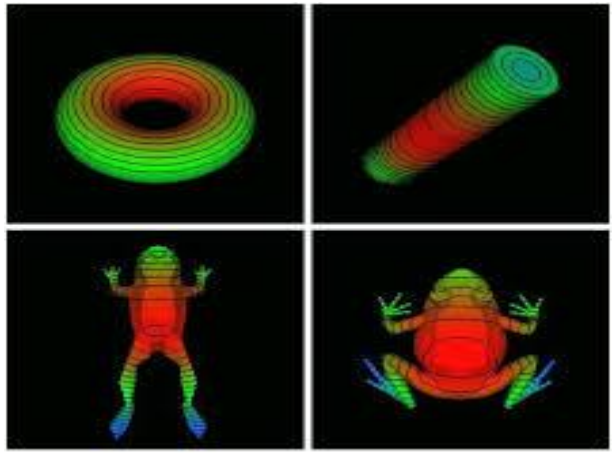


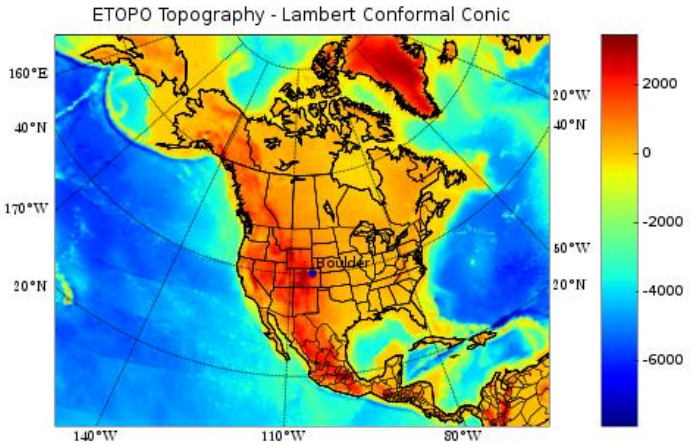


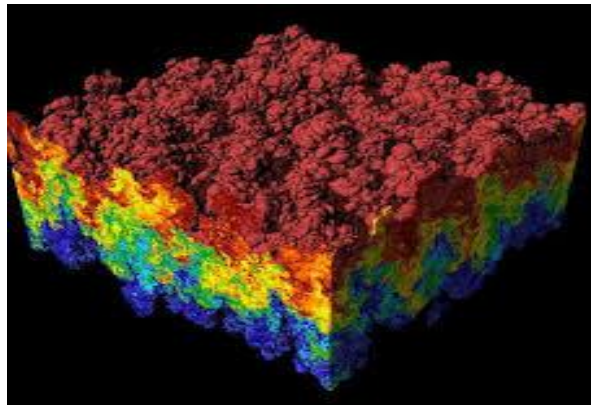
# Application Areas of Computer Graphics "Visualization"



- Various **techniques** can be used to represent the **large amount of data** obtained from **scientific, medical or business analysis.**
  - These includes **color coding, contour plots, graphs, charts** etc.





# Application Areas of Computer Graphics "Computer Art"



- Artist uses special purpose hardware and programs that provides facilities for designing object shapes and specifying object motion.
  - Examples pixel paint, super paint etc.

# Application Areas of Computer Graphics "Education and training"

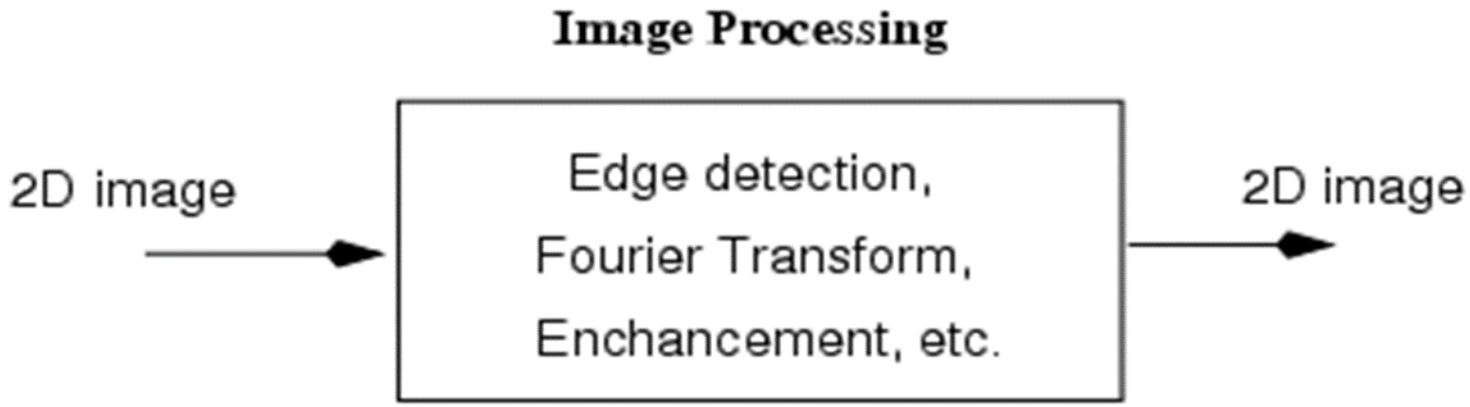


- Computer generated models of physical, financial and economic system are often used as **educational aids**.
  - Various kinds of **simulators program** can be used to provide the trainings.
  - E.g. automobile **driving** simulator.

# Application Areas of Computer Graphics "Image processing"



- Computer graphics is used to **create pictures.**
- Image processing applies techniques to **modify or interpret** the existing pictures. It is used to:
  - Improve picture quality
  - Machine perception of visual information



# Application Areas of Computer Graphics "Entertainment"

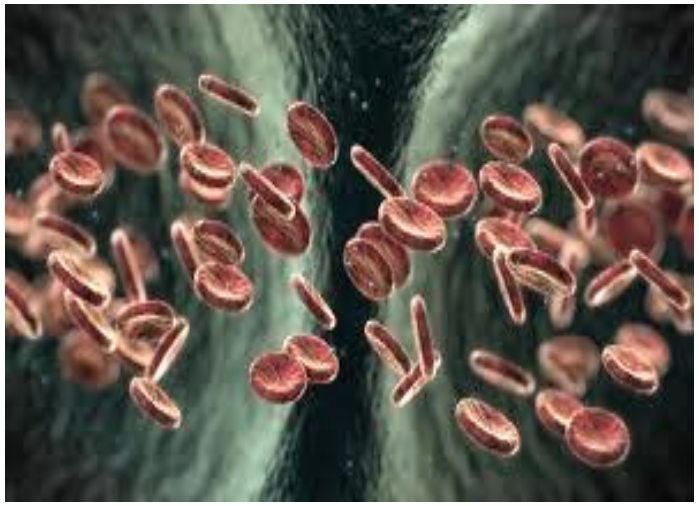


- **Computer graphics** methods are now commonly used in **making motion pictures, music videos , games** and **televisions shows.**
  - Sometime **graphics pictures** are displayed by themselves and sometime **combined** with the **actors and live scenes.**

# Application Areas of Computer Graphics "Medical Field"



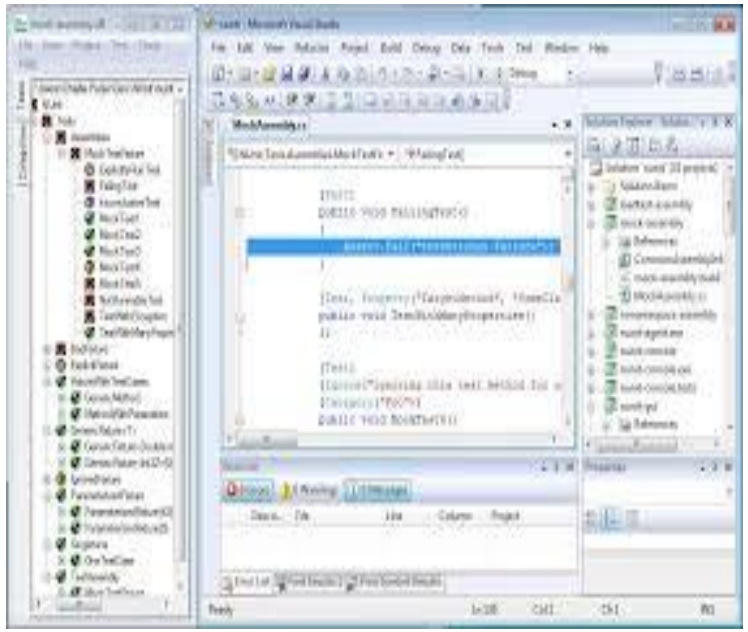
- Computer graphics can also be used to represent the various internal parts and process of the human body.



# Application Areas of Computer Graphics Graphical "User Interface(GUI)"



- It is the interface of the software that **communicates** with the user with help of some input devices.
  - It contains number of **windows , menus** and **icons** for **fast selection** of processing options (**WIMP**)



# Application Areas of Computer Graphics Graphical "Virtual Reality and Augmented Reality"



- Virtual Reality (VR) allows users to be *immersed* in a computer generated world, and to interact with it as if they were interacting with the **real world**.
- Typically, the user will **wear special hardware** such as the **VR-headset**

- **Augmented Reality (AR)** combines a **computer-generated virtual** world with the **real world**. In AR, computer-generated images are **overlaid** onto a user's view of the real world.
- **AR system** used for surgery, in which computer-generated images of hidden features such as **blood vessels and tumours** are overlaid on the surgeon's view of the patient through a surgical microscope.

# Application Areas of Computer Graphics



## Graphics Applications Examples

Entertainment: Cinema

Pixar: Monster's Inc.

Medical Visualizations

Visible Human Project

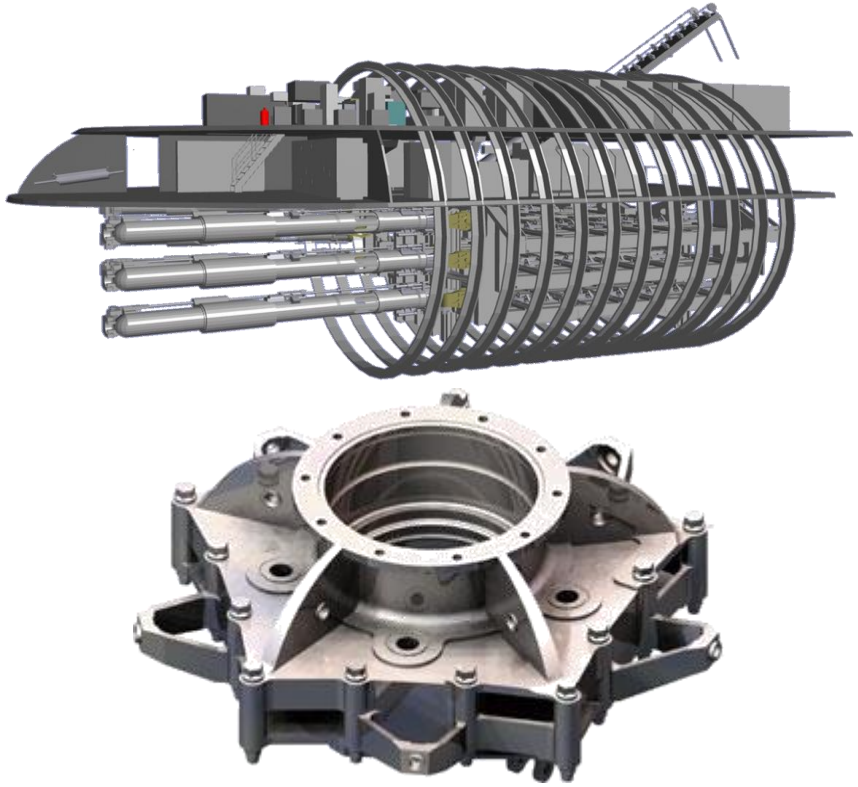
# Application Areas of Computer Graphics



## Graphics Applications Examples

Scientific Visualization


Computer Aided Design



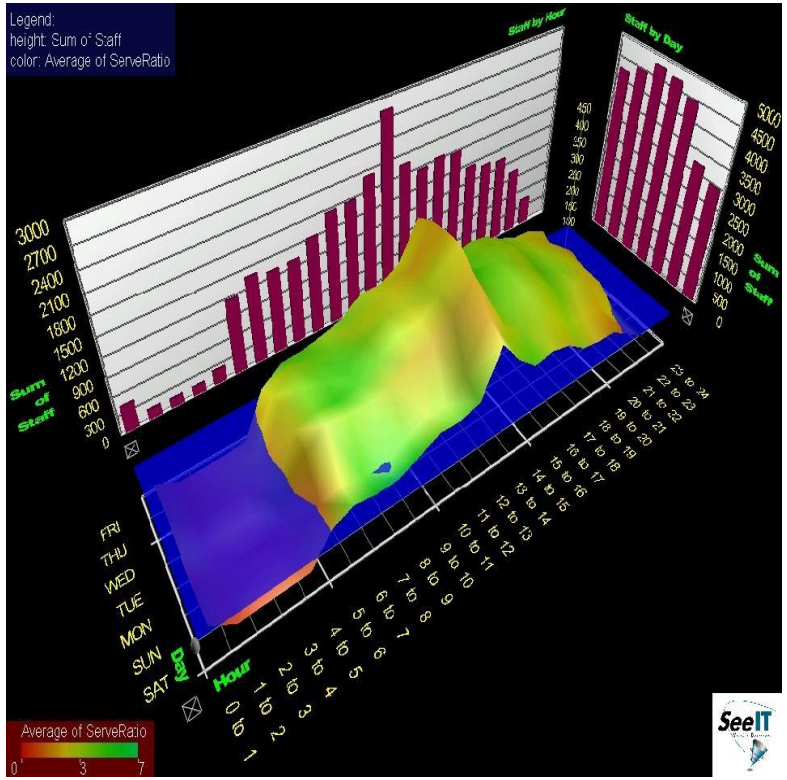
# Application Areas of Computer Graphics



## Graphics Applications Examples

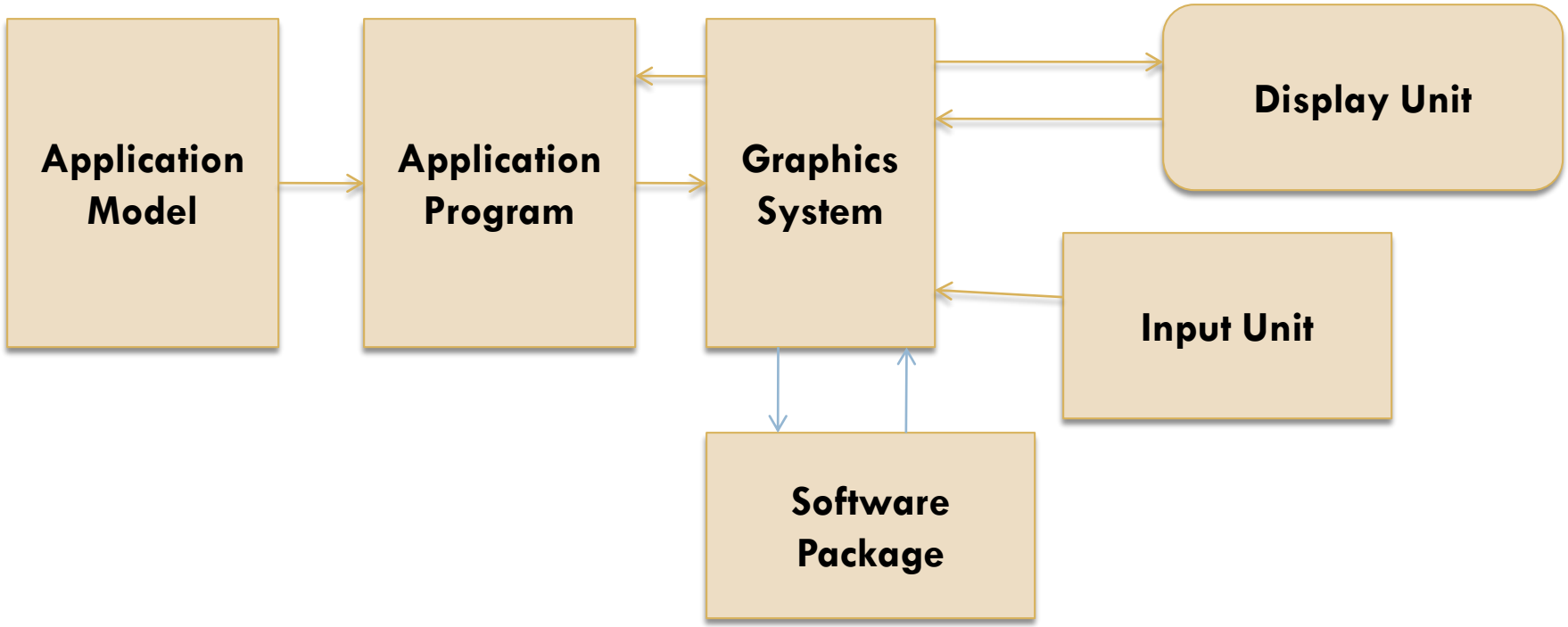
Entertainment: Games


Information Visualizations



# What Graphics Systems Consists?

- Typical **graphical system** consists of various software packages and host computer with support of **fast processor , large memory ,frame buffer** and
  - Display **devices/Output devices** (Monitors, printers, plotters)
  - Input devices (keyboards, mouse , joysticks)



# Graphical Display Devices



- **Display devices** are an output device used for the visual presentation of information for **Visual reception.**
  1. **Analog display devices (cathode-ray tubes)**
     - Oscilloscope tubes
     - TV CRTs
  2. **Digital display devices**
     - LED (including OLED) displays
     - LCD (liquid crystal) displays
     - VF (vacuum fluorescent ) displays
     - Nixie tube displays and PDPs (plasma display panels)
     - Electroluminescent displays (ELDs)
  3. **Others:**
     - Electronic paper, Laser TV etc.

# Graphical Display Devices



## Cathode Ray Tube (CRT)

- Invented by German physicist Karl Ferdinand Braun in 1897.
  - It is an evacuated glass envelope containing an ***electron gun*** (a source of electrons) and a ***fluorescent screen,*** usually with internal or external means to **accelerate and deflect** the electrons.
  - When electrons strike the **fluorescent screen, light is emitted.**
  - The **electron beam** is deflected and modulated in a way which causes it to **display** an **image on the screen.**
  - The image may represent ***electrical waveforms*** (***oscilloscope***), ***pictures*** (***television, computer monitor***), echoes of **aircraft detected** by **radar,** etc.

# Graphical Display Devices



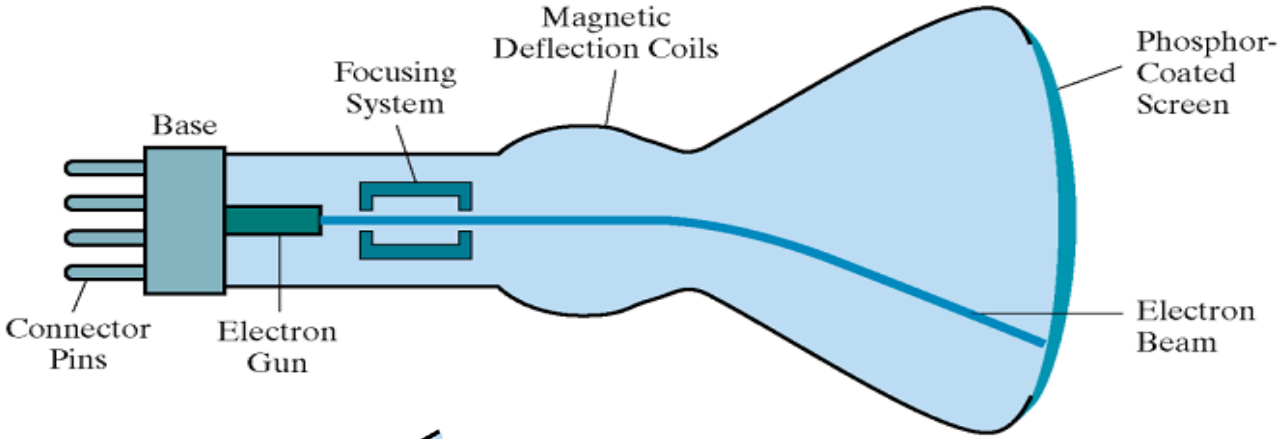
## Cathode Ray Tube (CRT)

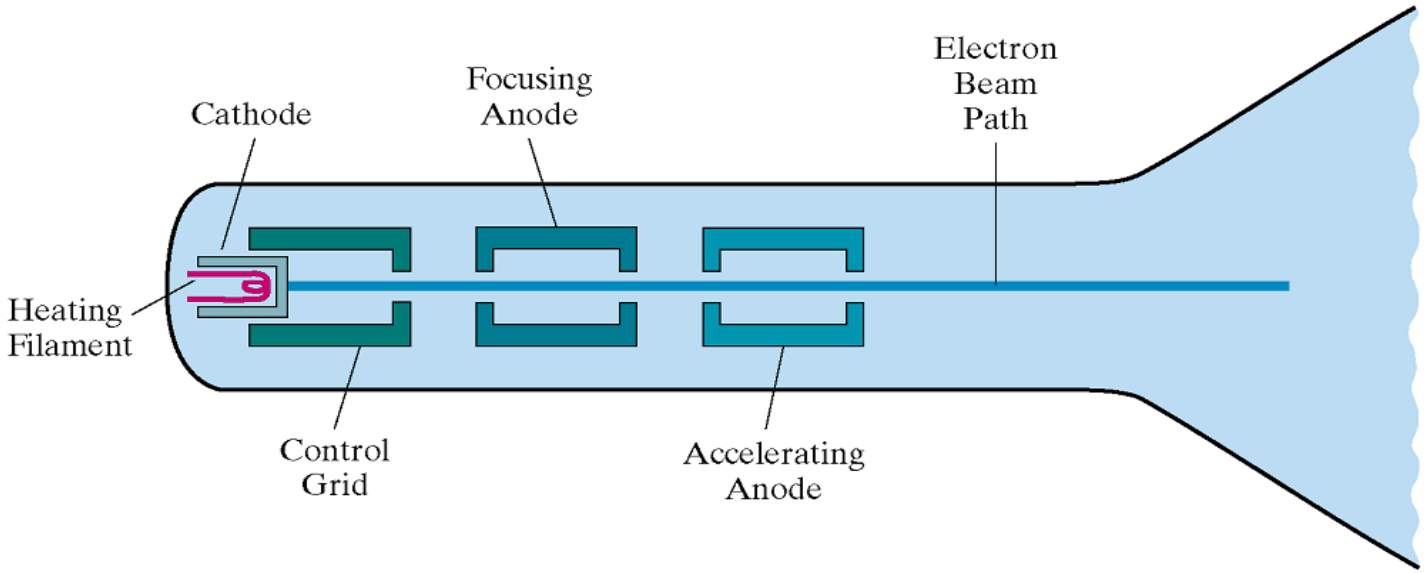
- A cathode ray tube (CRT) contains **four basic** parts:
  - ***Electron Gun*** – composed of heated metal cathode and control grid.
  - ***Accelerating Anode***
  - ***Focusing System***
  - ***Deflection system*** (Vertical and horizontal deflection plates)
  - **Phosphor Screen –** evacuated glass envelope/bottle with a phosphorescent screen that glows visibly when **struck** by the **electron beam.**

# Graphical Display Devices



## Cathode Ray Tube (CRT)



# Graphical Display Devices



## Cathode Ray Tube (CRT)

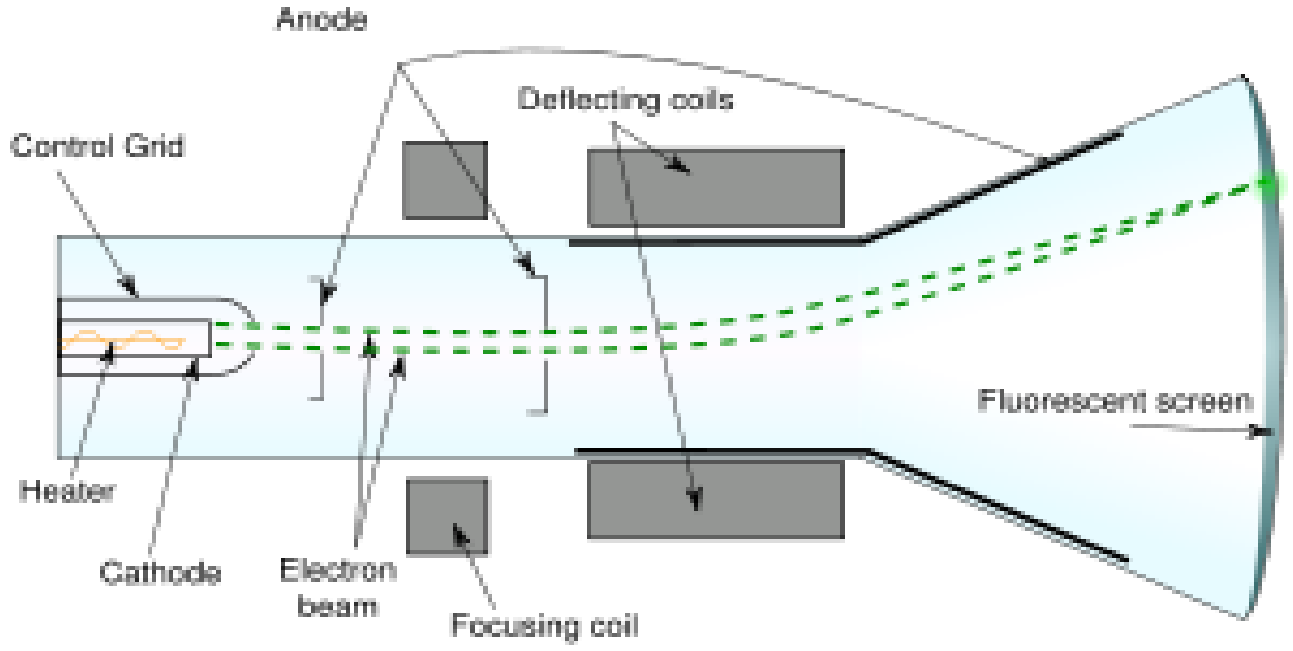
- **Electron Gun:**
  - An electron gun consists of a series of **electrodes** producing a narrow beam of **high-velocity** electrons.
  - Electrons are released from the indirectly **heated cathode**.
  - **Intensity** of the **beam** is controlled by variation of the **negative** potential of the **cylindrical *control grid*** surrounding the cathode.
  - This electrode is called the **modulator**.
  - The **control grid** has a hole in the front to allow passage of the **electron beam**.
  - The **negative voltage** applied at cylindrical control grid controls the intensity of electron beam by repealing electrons.
    - High (-ve) voltage stops electron passing from the hole of control grid while small (-ve) voltage decreases electron passage.

# Graphical Display Devices



## Cathode Ray Tube (CRT)

- **Electron Gun:**

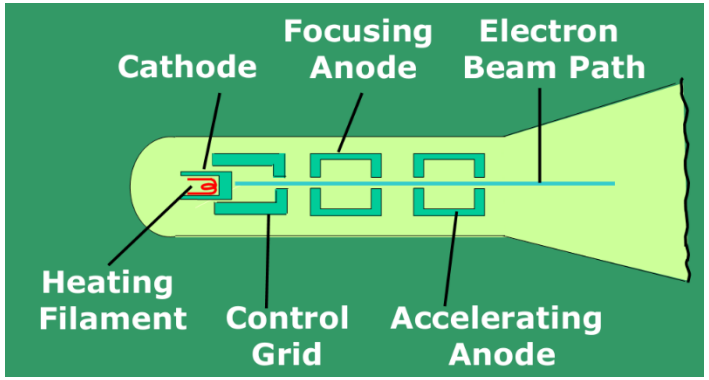


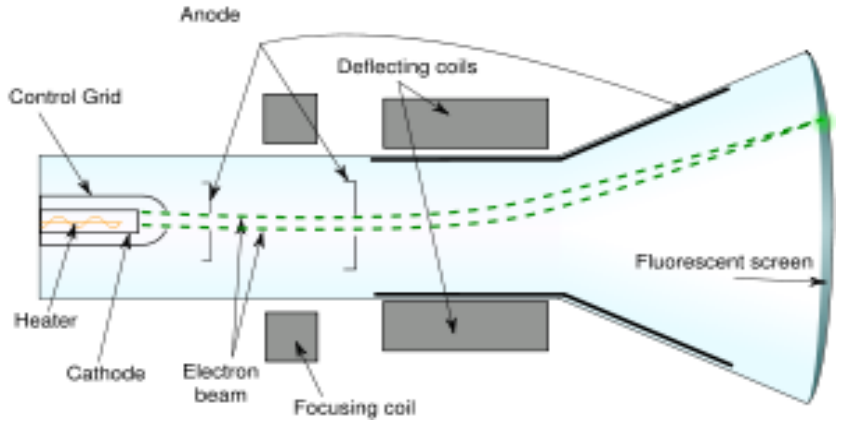
# Graphical Display Devices



## Cathode Ray Tube (CRT)

- **Focusing System:**
  - In a **CRT** the focusing system **acts** like a **light lens** with a **focal length** such that the **center of focus** is the screen.
  - Focusing system concentrates electron beam to a small spot.
    - In ***electrostatic focusing***, electrons pass through positively charged metal cylinder.
    - In ***magnetic focusing***, coils are mounted outside of **CRT** envelope which produces smallest spot.



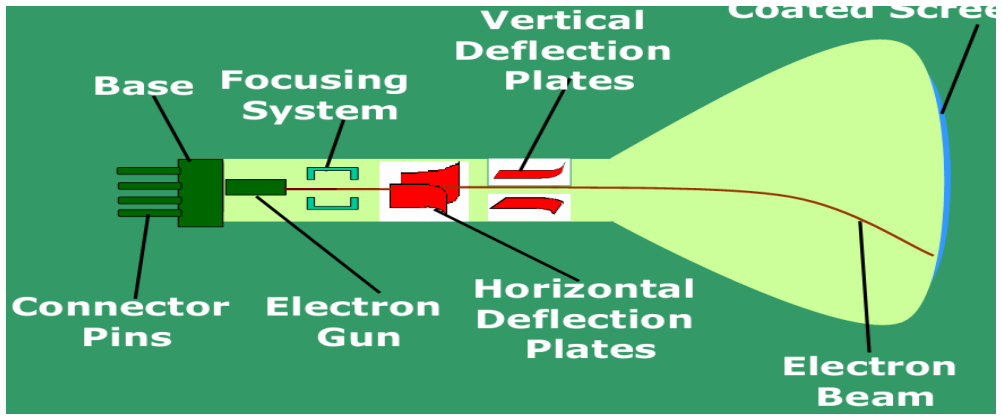



# Graphical Display Devices



## Cathode Ray Tube (CRT)

- **Deflection System:**
  - Deflection **System deflects/directs** electron beam horizontally and/or vertically to any point on the **screen.**
  - The ***horizontal and vertical deflectors*** allow the **electron beam** to be focused on any spot on the **screen.**
  - Can be controlled by electric (***deflection plates***) or magnetic fields (***deflection coils***).
    - Magnetic → two pairs of coils
    - Electrostatic → two pairs of deflection plates



# Graphical Display Devices



## Cathode Ray Tube (CRT)

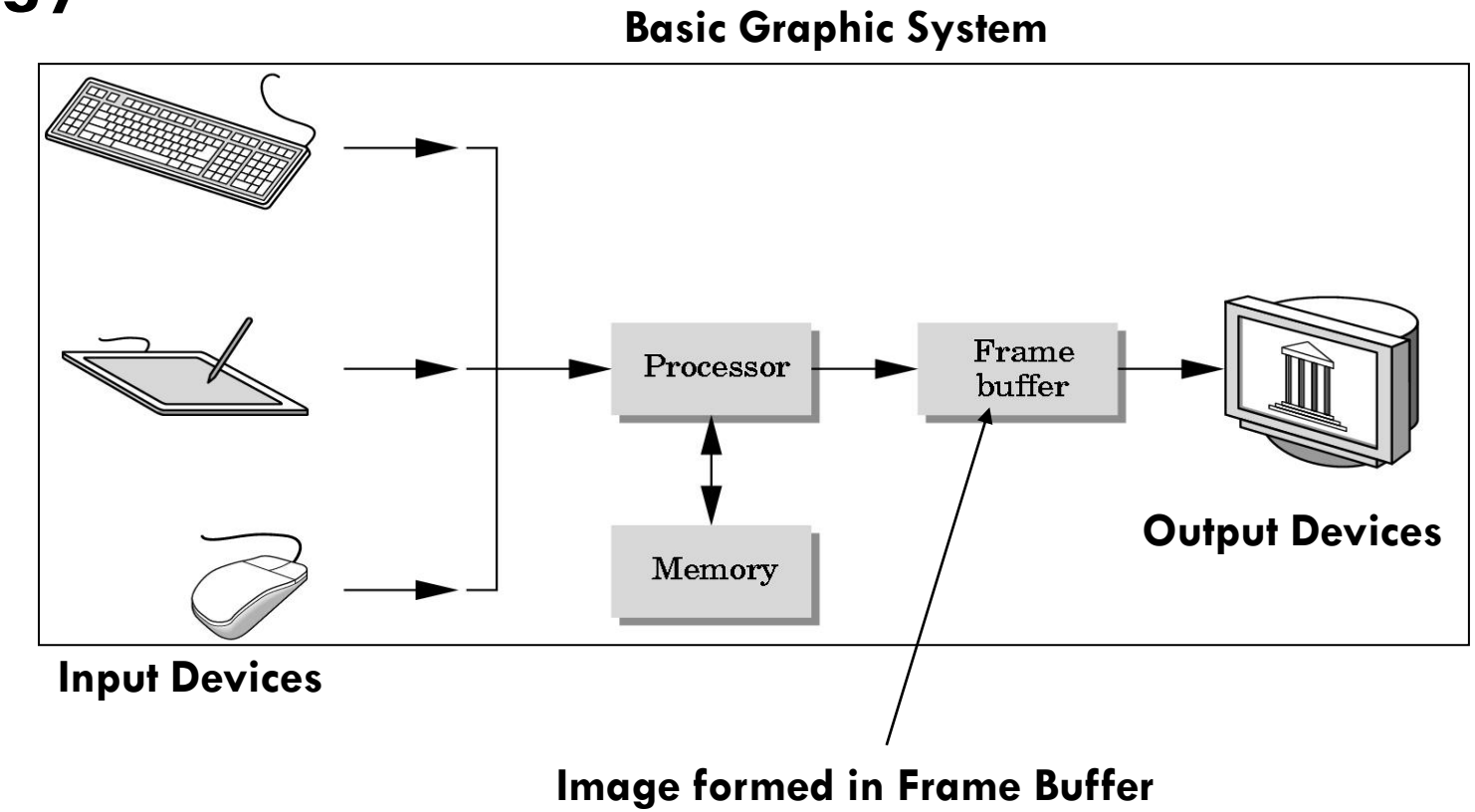
- **Phosphor Screen:**
  - The screen which is the front surface of the picture tube is coated with a **special organic compound** called a ***phosphor***.
  - Electrons are accelerated towards this phosphor screen with **high positive voltage** applied at accelerating anode.
  - When the beam hits a phosphor dot, it glows with a brightness proportional to the strength/intensity of the beam and how long it is hit.
  - For color systems there are groups of three different phosphors,
    - One to produce ***red shades***, one for ***green shades***, and one for ***blue shades***.
  - Electrons hit the **screen phosphor molecules** and cause a ground state to singlet excited state transition.
  - Most of the phosphors relax back to the ground state by emitting a photon of light which is called ***fluorescence***.
    - This happens very rapidly so that all of the molecules which fluoresce do so in under a millisecond.

# Graphical Display Devices



## CRT Display Technology

- Vector Display
- Raster Display



# Graphical Display Devices



## Vector Display Technology

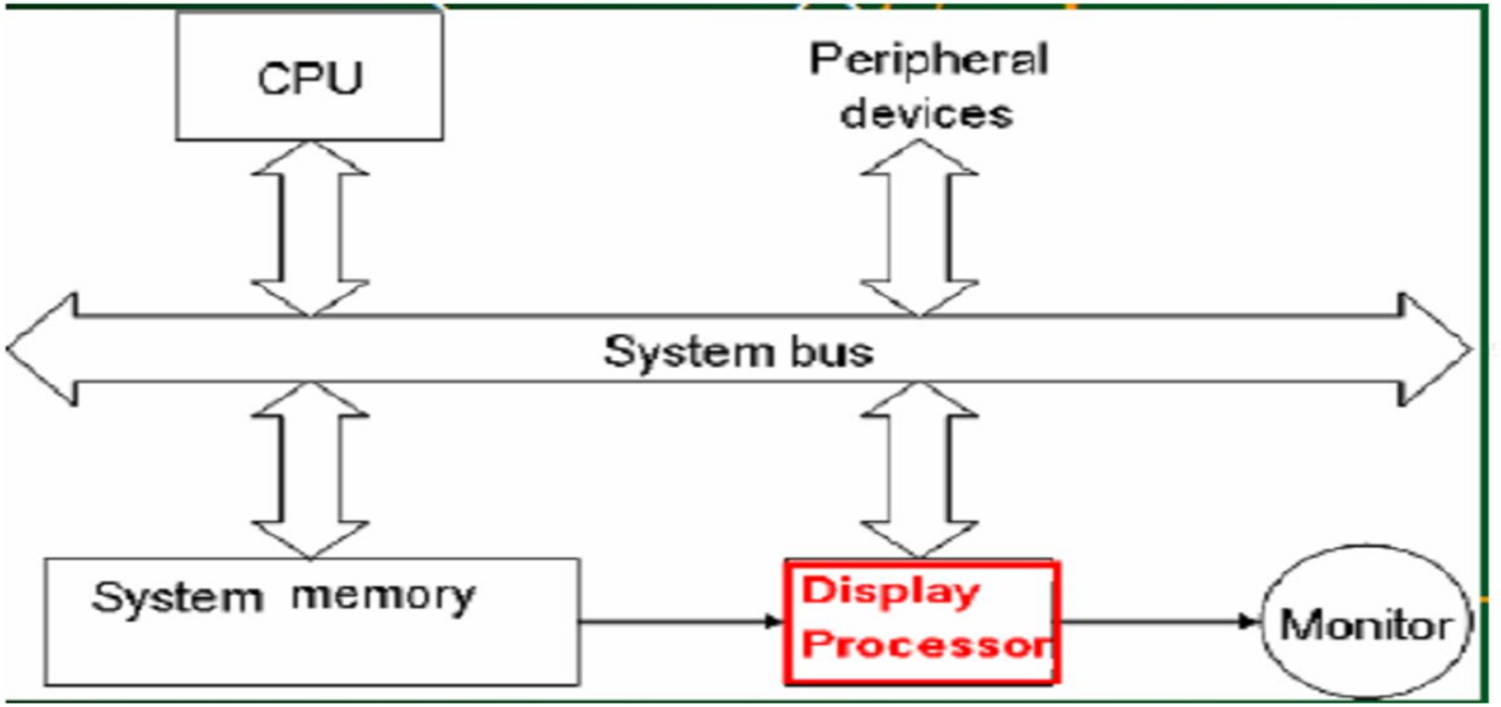
- Often termed **random scan displays**, ***stroke-writing***, or ***calligraphic displays***.
  - Electron beam is directed to the part of screen where picture is to be **drawn and directly draws** the picture in any specified order.
    - A **pen plotter** is an example of such a system.
  - Picture definition is stored as ***set of line-drawing commands*** in memory, are known as ***refresh display file*** (***refresh buffer***/***vector file***).
    - The display program (display file) has commands for point, line, and character plotting.
  - The electron gun of a CRT illuminates points and straight lines in any order.
    - To display a Picture, the system cycle through the set of commands in the display file, drawing each component line in turn.

# Graphical Display Devices



## Vector Display Technology

- **Architecture** – Random System

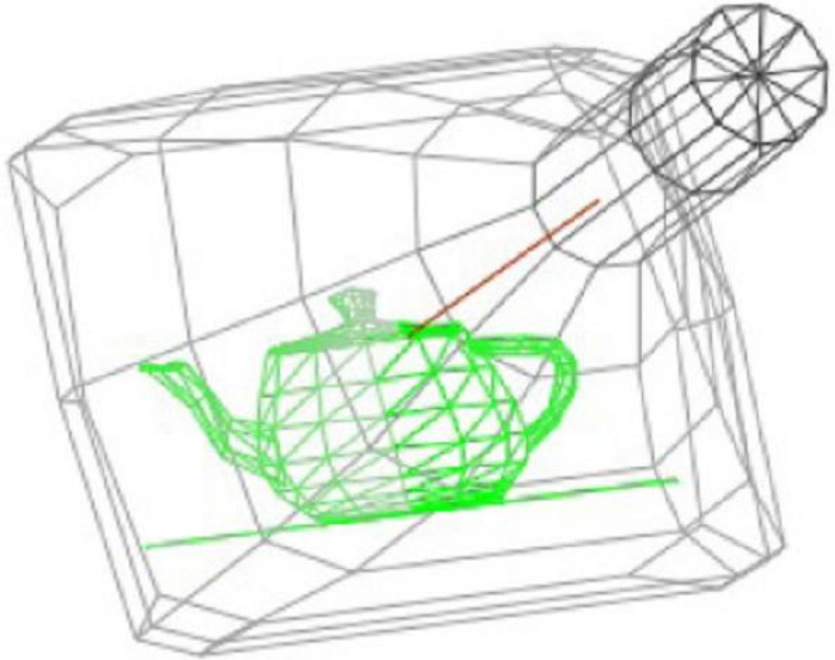


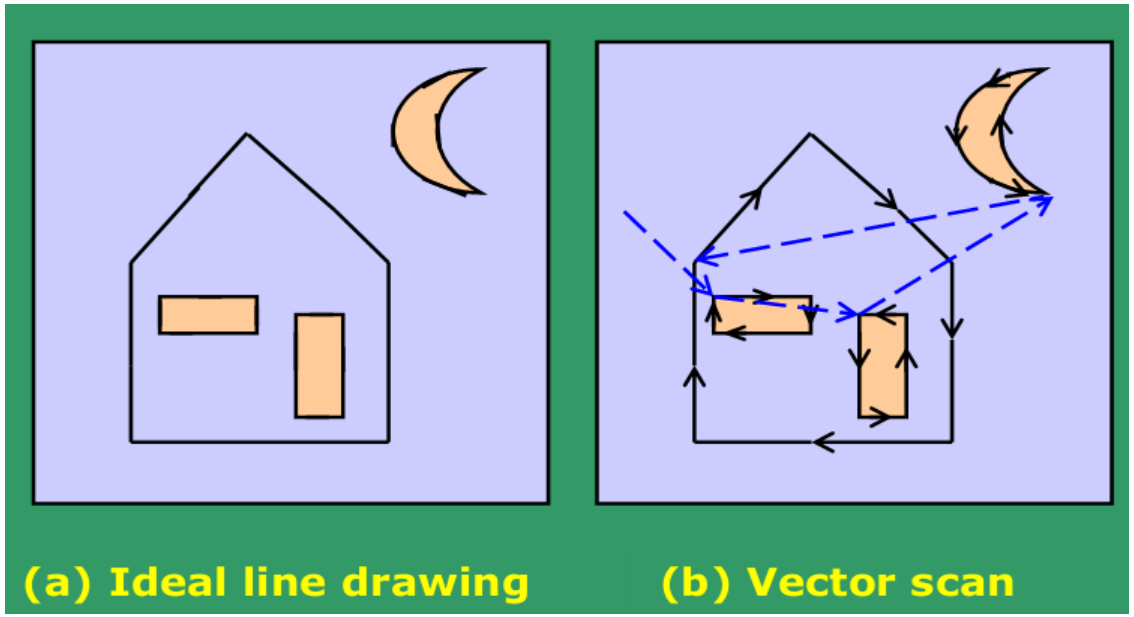
# Graphical Display Devices



## Vector Display Technology

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





# Graphical Display Devices



## Vector Display Technology

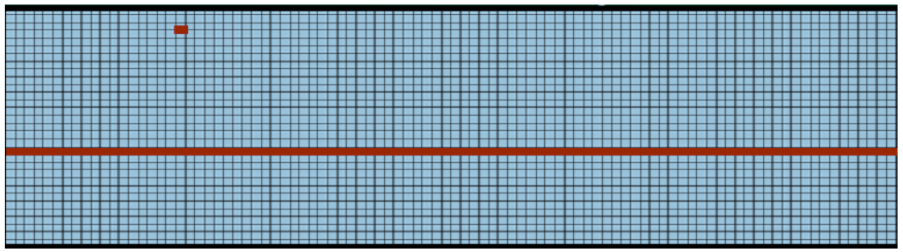
- **Advantages:**
  - Very high resolution, limited only by **monitor**.
  - Easy animation, just draw at **different positions**.
  - Requires **little memory** (just enough to hold the **display program**).
- **Disadvantages:**
  - Requires intelligent electron beam, i.e., processor controlled.
  - Limited screen density before have flicker, can't draw a complex image.
  - Limited color capability (very expensive).
  - Improved in the 1960's by the **Direct View Storage Tube** (**DVST**) from Tektronix.

# Graphical Display Devices



**Raster Scan Display Technology**

- Raster is a series of adjacent parallel **'lines'** which together form an image on a **display screen.**
  - In early analogue television sets each such line is **scanned continuously,** not broken up into **distinct units.**
  - In **computer or digital displays** these lines are composed of independently **colored pixels** (**picture elements**)
- Raster Scan is the representation of images as a collection of ***pixels/dots*** (a rectangular array of points or dots).
  - **Pixel:** one dot or picture element of the raster.
  - **Scan line:** a row of pixels.

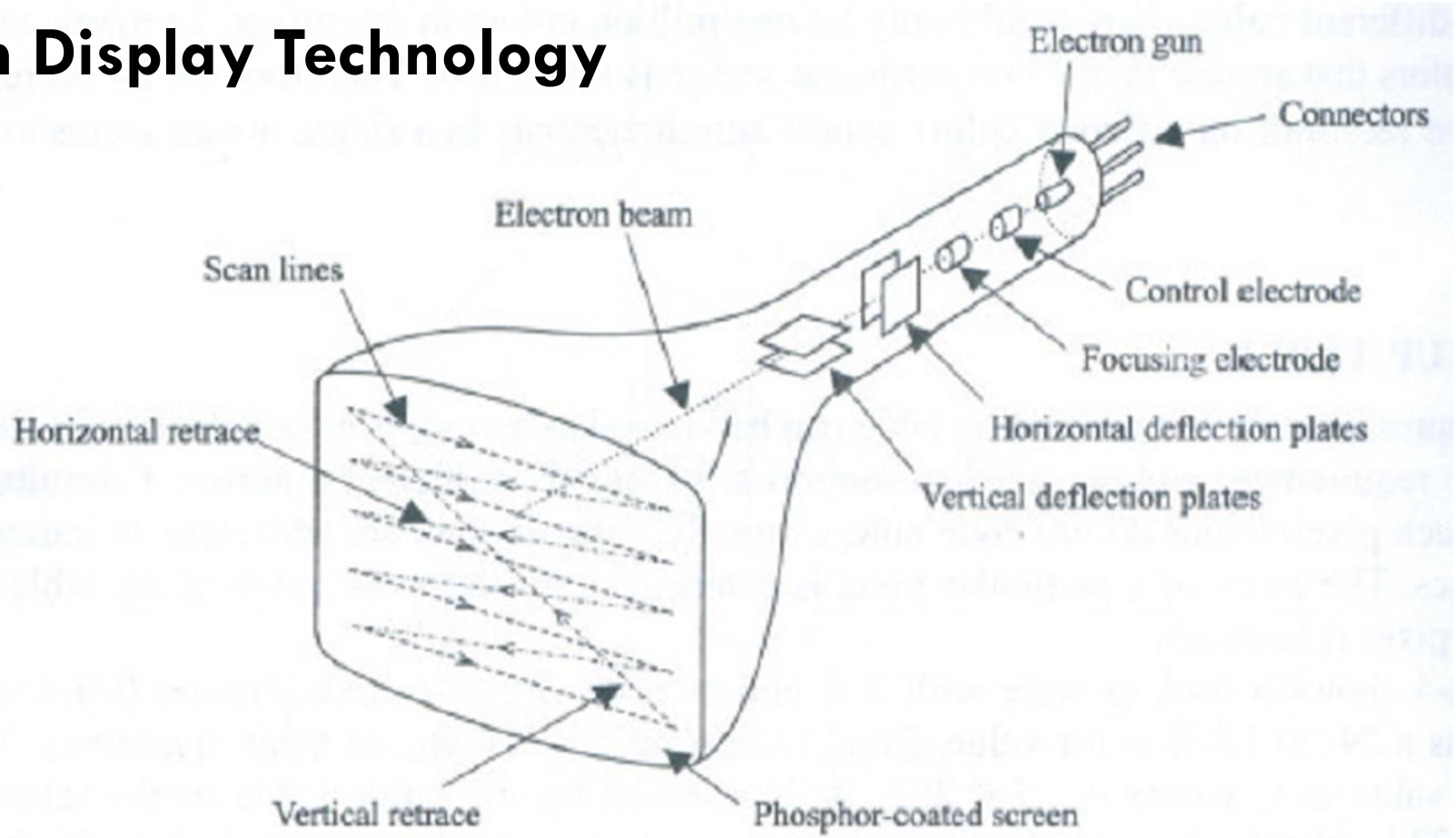


- Unlike DVST and random-scan which were line-drawing devices, ***refresh CRT*** is a point-plotting device.
  - Example: **Home television sets** and printers.

# Graphical Display Devices



## Raster Scan Display Technology



# Graphical Display Devices



**Raster Scan Display Technology – How it works:**

- Raster is stored as ***matrix of pixels*** representing entire **screen area** (i.e. entire screen is a matrix of pixels) and the brightness of each pixel can be **controlled** by the intensity of the **electron beam.**
  - **Refresh buffer** can be visualized as a set of horizontal raster lines or a row of individual pixels.
  - Entire image is scanned out sequentially by the video controller (one raster line at a time), i.e. the raster lines are **scanned** from top to bottom and then back to the top.
  - Line cannot be drawn directly from one point to another, and each point is an addressable point in screen and memory.
    - This causes the effect of '***aliasing***', '***jaggies***' or '***staircase***' effect.
  - At least one memory bit for each pixel (called ***bit-plane***) is required.
  - **Refresh/Frame** buffer is also called ***Bit-plane***.

# Graphical Display Devices

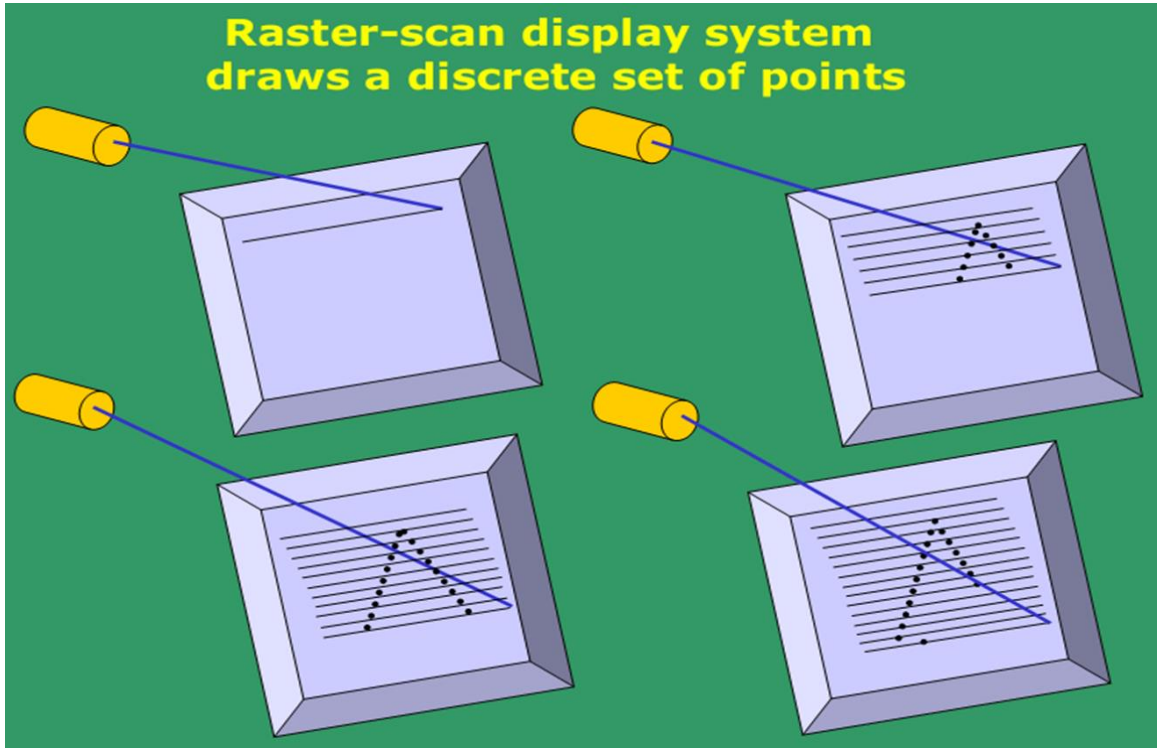


**Raster Scan Display Technology – How it works:**

- **Refreshing rate** for raster scan **display** is usually **60 to 80** frames per second.
  - i.e. **1/80 or 1/60** seconds is **taken**

    for electron beam to scan from

    top left corner to bottom right corner.



# Graphical Display Devices



**Raster Scan Display Technology – How it works:**

- **Refresh rate:** 24 is a minimum to avoid flicker, corresponding to 24Hz.
  - Current raster-scan displays have a refresh rate of **at least 60 frames** (60 Hz) per second, up to 120 (120 Hz).
- **Refresh procedure:**
  - **Horizontal retrace** – beam returns to **left of screen**.
  - **Vertical retrace** – bean returns to top **left corner of screen**.
- **Interlaced refresh** – display first even-numbered lines, then odd-numbered lines permits to see the image in half the time
  - Useful for slow refresh rates (30 Hz shows as 60 Hz).
- **Depth of the buffer area** is the number of bits per pixel (***bit planes***), up to 24.

# Graphical Display Devices



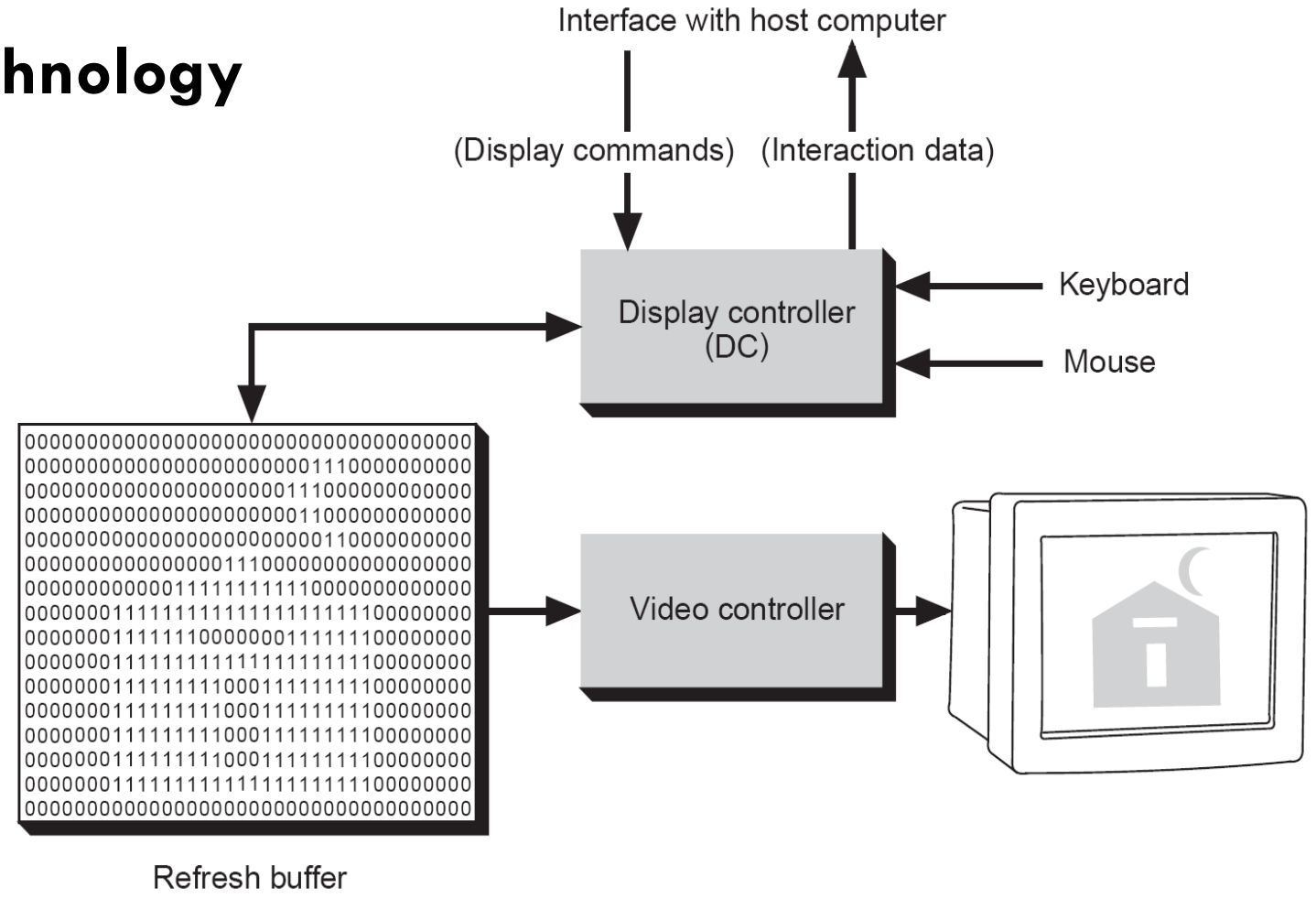
## Raster Scan Display Technology

- In Raster Scan Display
  - A ***display controller*** stores the screen content and other graphics information in a graphics ***memory***.
  - The content of the graphics memory is read by the ***video controller*** at the display's frame rate, converted from digital to **analog and transferred** to display ***pixel rows*** and ***columns***.

# Graphical Display Devices



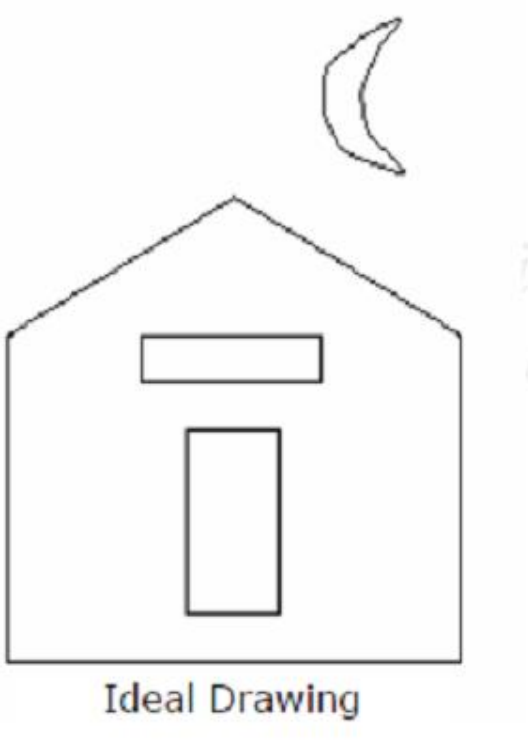
## Raster Scan Display Technology

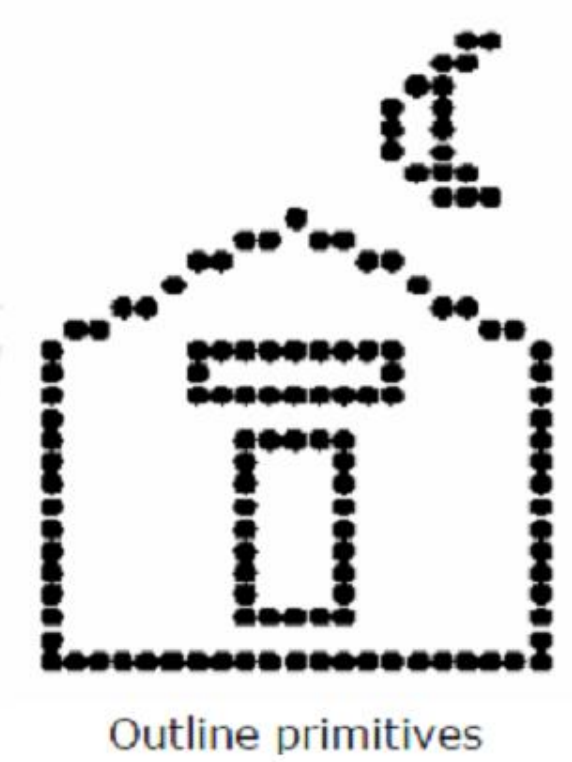


# Graphical Display Devices



## Raster Scan Display Technology – How it works:



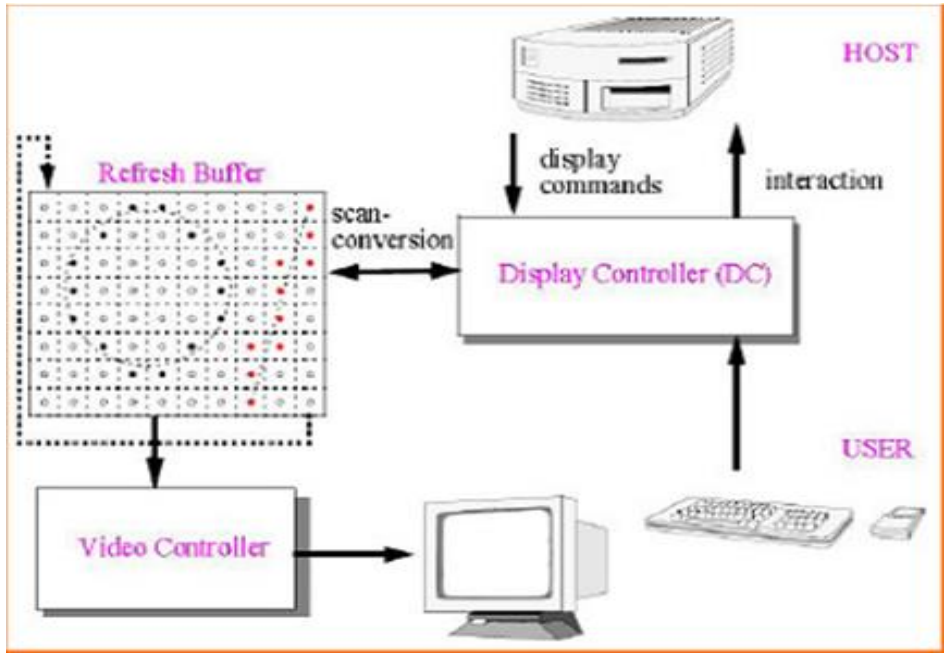



# Graphical Display Devices

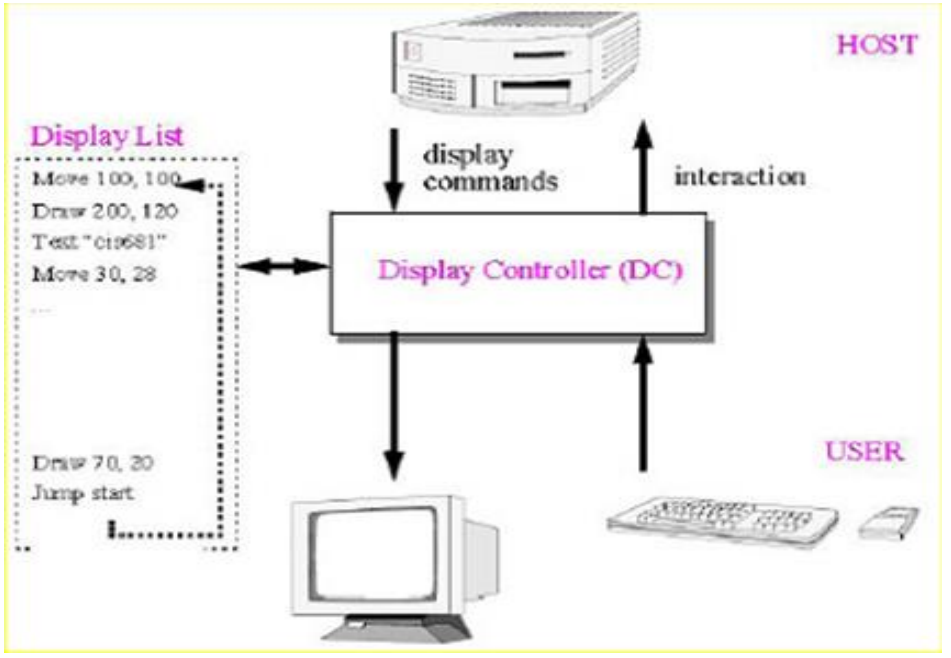


## Raster Scan vs. Random Scan

**Raster Scan System**




**Random Scan System**

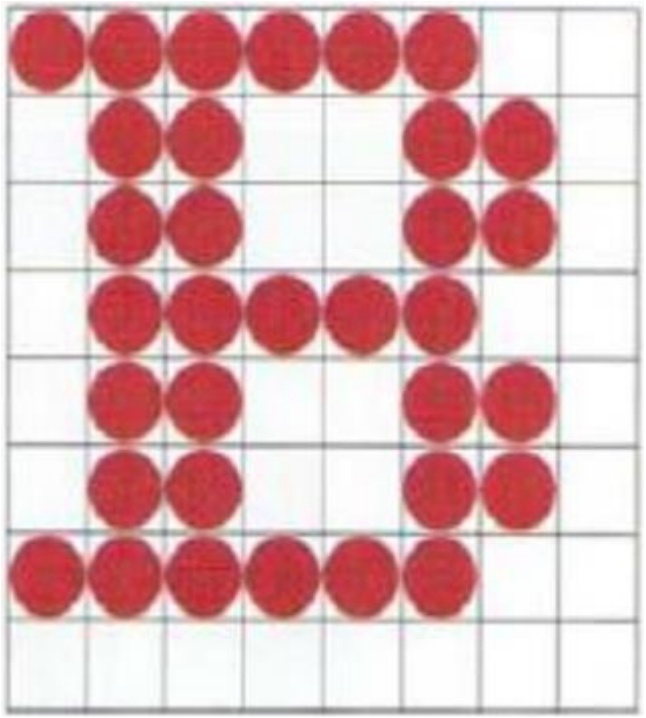


# Graphical Display Devices

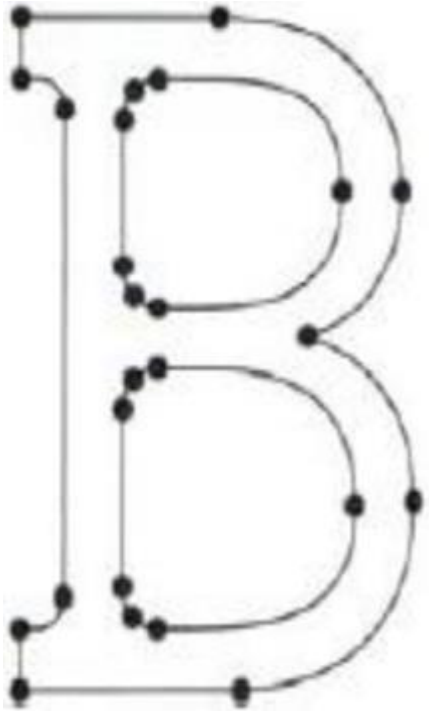


## Raster Scan vs. Random Scan

**Raster Scan System**



**Random Scan System**



# Graphical Input Devices



- Graphics system make use of different types of input devices for data input. Some of the devices include:
  - Locator Devices
  - Keyboard
  - Scanner
    - Images
    - Laser
  - Cameras (research)

# Graphical Input Devices



**Locator Devices:**

- When queried, locator devices return a position and/or orientation.
  - **Mouse (2D and 3D)**
    - Pointing device to position cursor.
    - Wheel or rollers are used to record the amount and direction of movement.
    - Optical mouse uses optical sensors to detect mouse motion.
    - **One, two or three buttons** are included.
  - Trackball
  - Joystick (2D and 3D)

# Graphical Input Devices



**Locator Devices:**

- When queried, locator devices return a position and/or orientation.
  - Tablet
  - Virtual Reality Trackers
    - Data Gloves
    - 

# Graphical Input Devices



**Keyboards:**

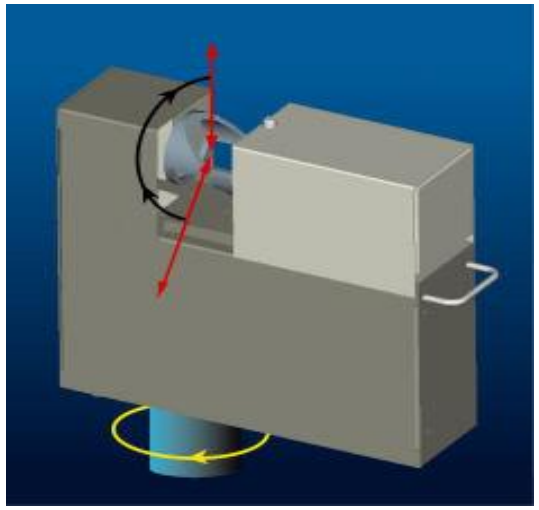
- **Text input:** ASCII keys are used to input text string.
  - Provides with features to facilitate entry of screen coordinates, menu selections or graphics functions.
  - Function keys allow user to enter frequently used operations in a single stroke and cursor.
  - Control keys are used for **cursor position or picture selection**.
    - **List boxes**, GUI
    - CAD/CAM
    - Modeling
- **Hard coded:**
  - Vertex locations are inserted into code.
- Some keyboards consist of **trackball** or **joystick**.

# Graphical Input Devices



**Scanners:**

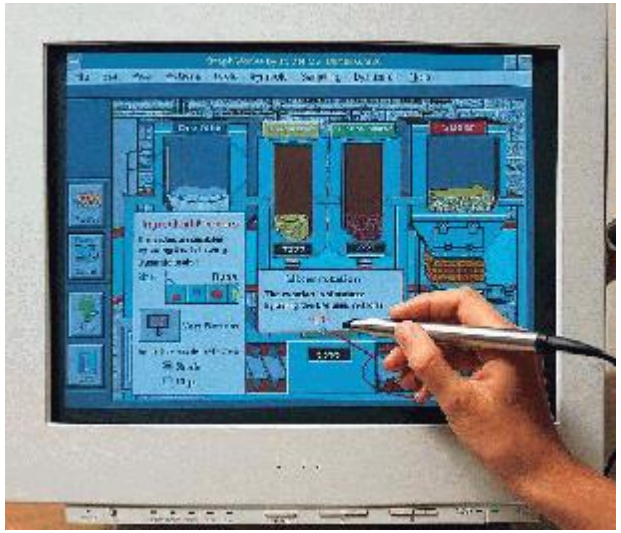
- Image Scanners - Flatbed, etc.
  - The type of data returned is ***Bitmap***.
- Laser Scanners – Deltasphere
  - Emits a laser and does time of flight.
  - Returns 3D point
- Camera based – research
  - Examine camera image(s) and try to figure out vertices from them.

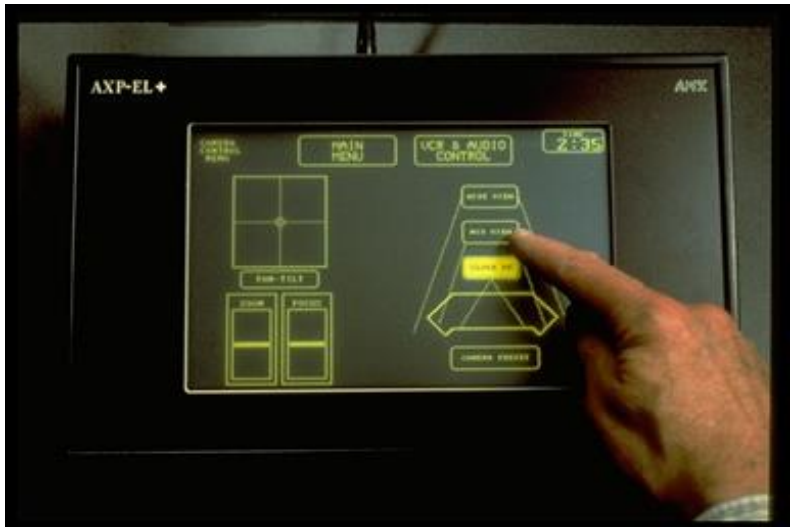


# Graphical Input Devices



- Many others:
  - Light Pens
  - Voice Systems
  - Touch Panels
  - Camera/Vision Based

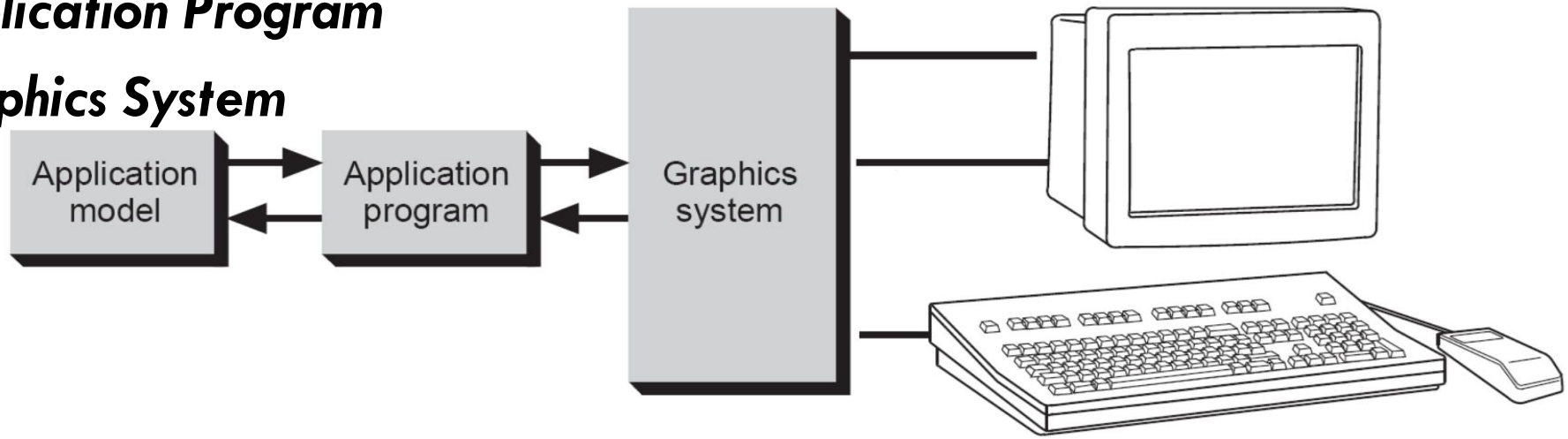




# Computer Graphics – Systems Architecture



- A computer graphics system consists of the subsequent basic components:
  1. ***Application Model***
  2. ***Application Program***
  3. ***Graphics System***



# Computer Graphics – Systems Architecture



1. **Application model**: contains data and objects that are to be displayed on a monitor, such as a scene description or an image file of a vector graphic.
2. **Application Program**: creation of graphical content based on an application model.
   - Transfer of graphical content to the graphics system is by means of graphical output commands.
     - Output commands specify, what is to be shown on the display and how it should be rendered.
   - **Storage of graphical content.**
   - Example: MS Windows®: **classes and methods** of the GDI (Graphics Device Interface).

# Computer Graphics – Systems Architecture



3. **Graphics system** – the graphics card including ***graphics chip*** and ***memory***:
   - Processing of scene content for display rendering based on application model commands.
   - Transfer of user input commands to the application model.
   - The designer of an **application software** has to determine
     - which objects and data classes can be generated and
     - which user interactions have to be taken into account.

# Computer Graphics – Systems Architecture



**Graphics Processing Unit(GPU)**

- In the recent years GPUs have evolved into **programmable and powerful graphics engines**.
- High level parallelism and programmability enable real time computation of complex real world scenes and physical Phenomena.
- **Requirements of GPUs** are:
  - Huge amounts of data must be processed.
  - Data have to be organized to be processed concurrently.
  - The latency of individual operations is less relevant than the overall throughput.
- GPUs have become GPGPUs (General Purpose GPU).

# Computer Graphics – Systems Architecture



## Graphics Processing Unit(GPU)

- Example: The GeForce 8800 GTX GPU consists of
  - 8 streaming multiprocessors
  - with 16 stream processors each.
  - The stream processors are also called "**unified shaders**" and can compute all necessary **operations** for vertices and pixels.
  - The same operations are performed on **multiple** data concurrently.
    - Such a computer architecture is called SIMD (Single Instruction, Multiple Data).

# Software Standards – GKS, PHIGS, OpenGL



- The primary goal of standardized graphics software is ***portability***.
  - Without standards, programs designed for one hardware system often cannot be transferred to another system without extensive rewriting of the programs.
- The first graphics software standard adopted by ISO and by ANSI is the **General Kernel System (GKS)** in 1984.
  - It was designed as a 2D graphics package, later extended to 3D graphics package.
- The second software standard to be developed and approved by the ISO was **P**rogrammer's **H**ierarchical **I**nteractive **G**raphics **S**ystem (**PHIGS**), which is an extension of GKS.
  - **PHIGS** provided increased capabilities for
    - hierarchical object modeling,
    - color specifications,
    - surface rendering, and
    - picture manipulations
- Subsequently, an extension of PHIGS, called **PHIGS+**, was developed to provide 3D surface-rendering capabilities not available in PHIGS.

# Software Standards – GKS, PHIGS, OpenGL



**GL** and **OpenGL**

- Along with the development of GKS and PHIGS, a set of routines called **GL** (**Graphics Library**), which very soon became a widely used package in the graphics community, and later became a de-facto graphics standard.
- The **GL** routines were designed for *fast, real-time rendering*, and soon this package was being extended to other hardware systems.
- As a result, **OpenGL** was developed as a hardware-independent version of **GL** in the early 1990s.
  - This **graphics package** is now maintained and updated by the OpenGL Architecture Review Board, which is a consortium of representatives from many graphics companies and organizations.
  - The **OpenGL** library is specifically designed for efficient processing of 3D applications, but it can also handle 2D scene descriptions as a special case of **three dimensions** where all the *z* coordinate values are 0.

# End of CH1!



**Thank You!!!**