Computer Graphics

Chapter 2
Computer Graphics Hardware

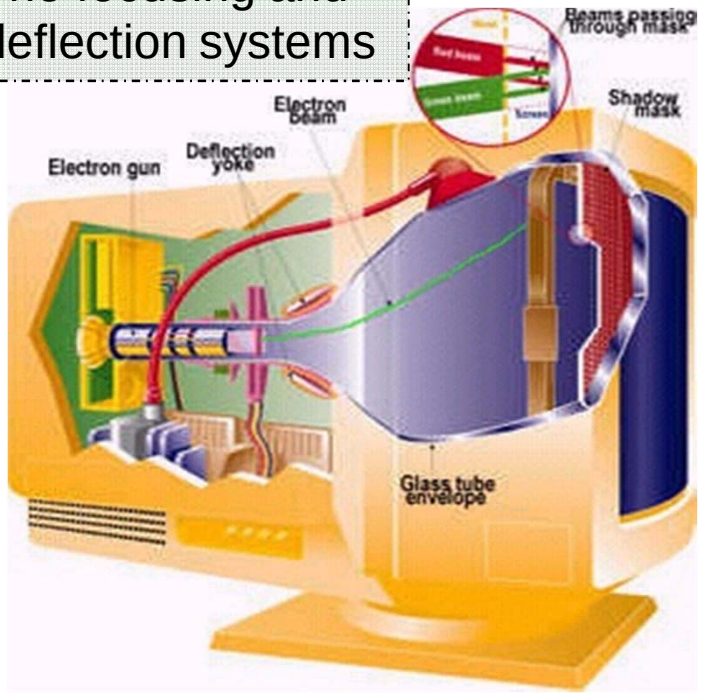
Outline

- **Video Display Devices**
  - **CRT**
  - **LDC**
- **Input Devices**

Video Display Devices

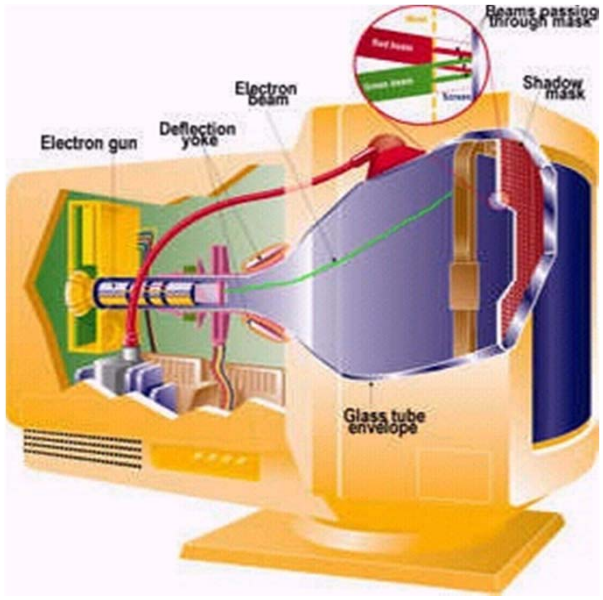
- Cathode Ray Tube (CRT, 陰極射綫管) display
  - High resolution
  - Good color fidelity
  - High contrast (400:1)
  - High update rates
- A beam of electrons (電子束) emitted by an electron gun, passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor(磷)-coated screen.

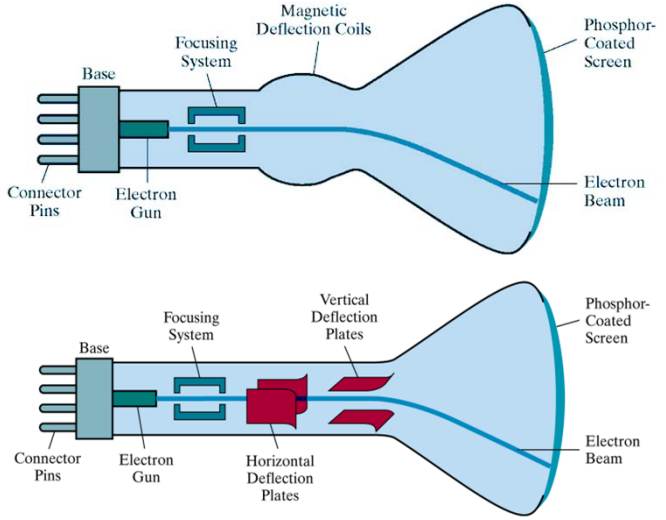
The focusing and deflection systems



Focusing and Deflection of CRT

- The focusing system: forces the electron beam to converge to a small cross section as it strikes the phosphor
- The deflection system: forces the electron beam spread out as it is near to the screen
- They can be controlled with either electric or magnetic fields.





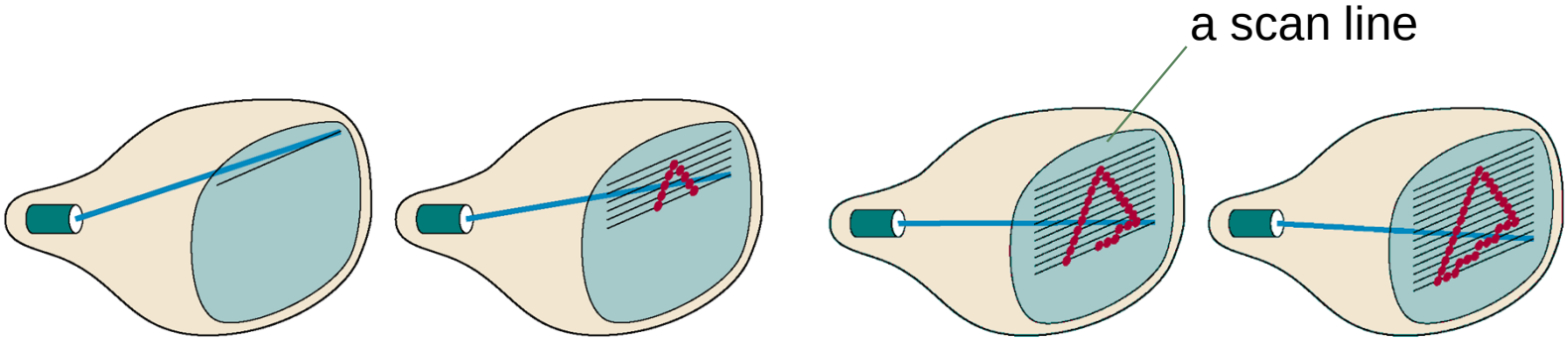
Refresh CRT

- **Refresh -** Redrawing the picture repeatedly
  - Because the light emitted by the phosphor fades very rabidly, the refresh process is needed to maintain the picture.
  - Implemented by quickly directing the electron beam back over the same screen points.

- Refresh rate (frame/sec. or Hz): the number of a picture (or a frame) is redrawn on the screen per second.
  - E.g.: a refresh rate of 60Hz means 60 frames per sec.

Raster-Scan Displays

- Raster scan methods have became the dominant technology since about 1975.
  - The electron beam is swept across the screen, one row at a time



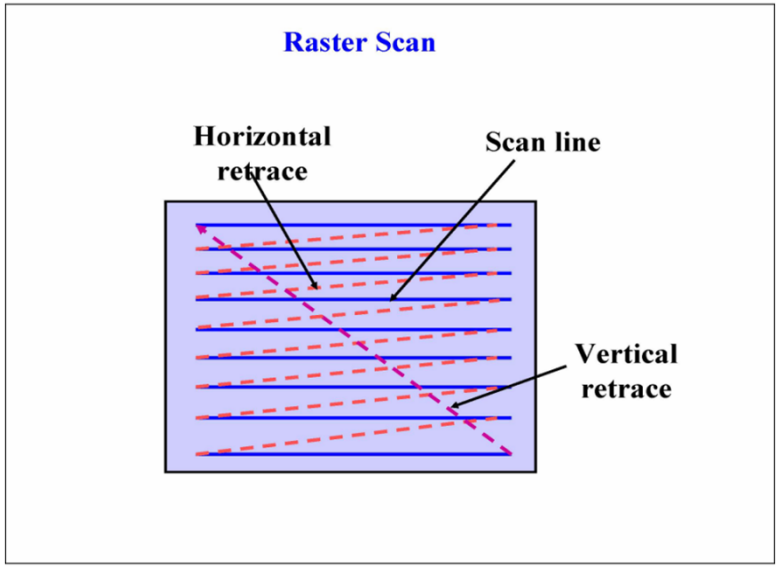
  - Frame: the total screen area
  - Pixels or pels (**p**icture **el**ements): the screen consists of a regular grid of spots.
  - Resolution: the maximum number of points that can be displayed without overlap on the screen.
  - Aspect ratio: the width divided by the height.

Raster-Scan Displays

Electron beam sweeping:

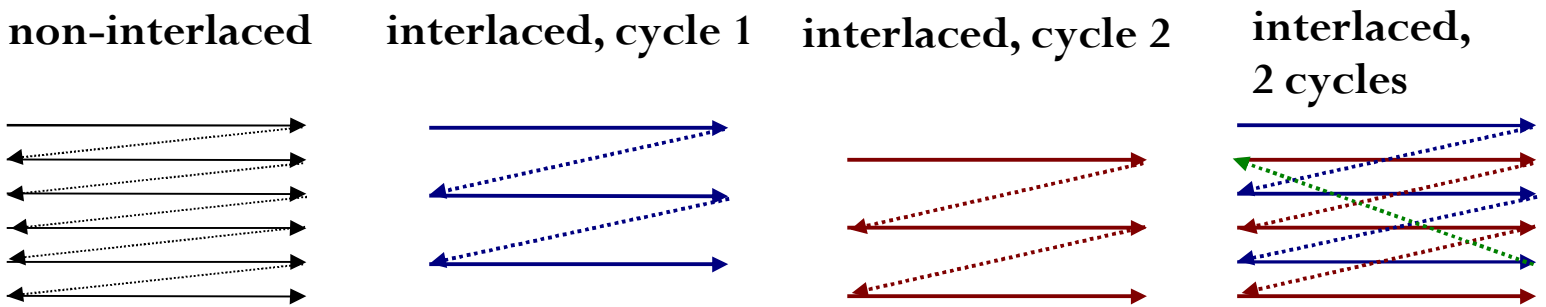
- Horizontal retrace: after refreshing each row, the electron beam returns to the left of the screen.

- Vertical retrace: after refreshing the whole screen, the electron beam returns to the top left corner of the screen for the next new frame.



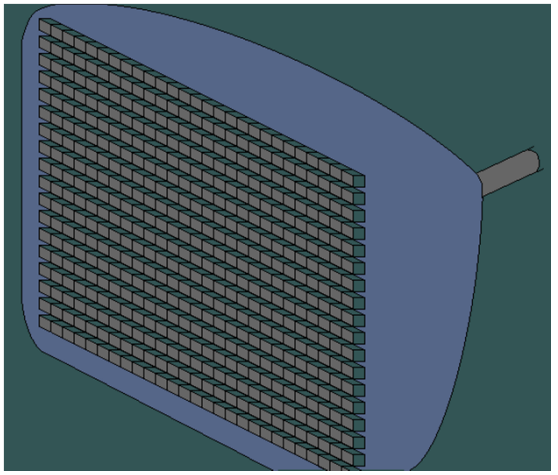
Raster-Scan Displays

- Interlacing: each frame is displayed in two passes



- Avoid noticeable flicker with slower refresh rates.

  E.g: actually 25Hz, if interlaced 50Hz to see the entire screen displayed (in half the time).



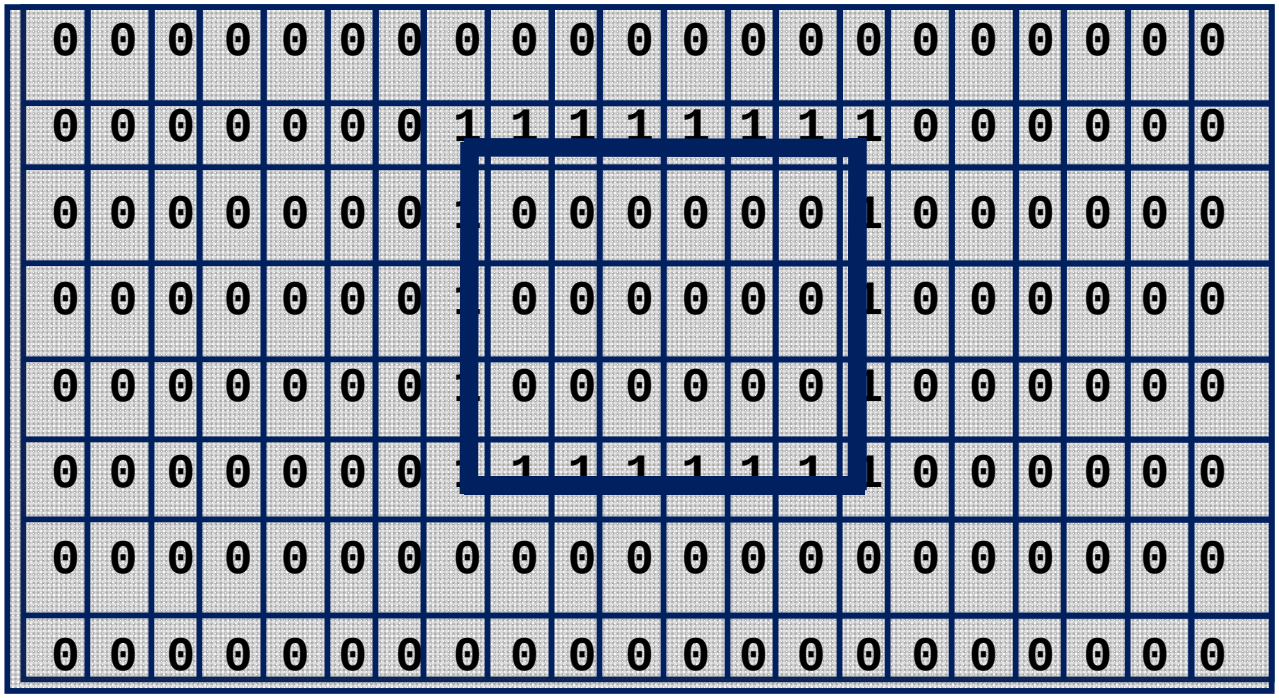
Raster-Scan Displays

- Terms
  - **Pixel**: each screen spot.
  - **Scan line**: each row of the screen.
  - **Frame**: the total screen.
  - **Resolution**: the maximum number of pixels that can be displayed on a screen without overlapping.
  - **Frame buffer** (refresh/color buffer): the memory area which stores the color value of one frame.

Frame buffer holds the contents of what will be displayed.

What goes on inside the computer to generate something (e.g.: rectangle) on the screen?

Frame Buffer



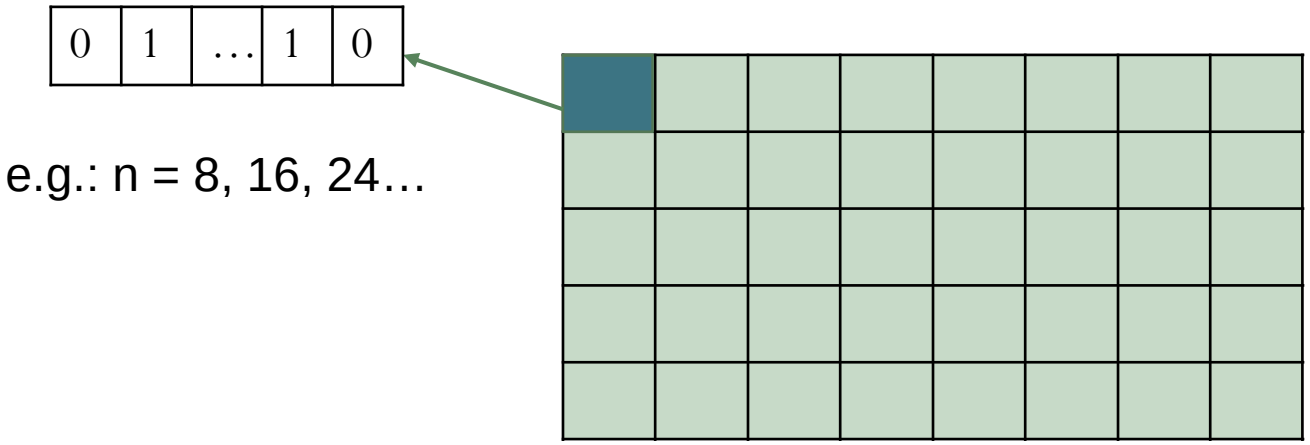
Questions:

What is the largest image we can display?

How much memory do we need to allocate for the frame buffer?

Frame Buffer

- Black-and-white system: one bit for each pixel
- More colors: n bits per pixel



e.g.: n = 8, 16, 24…

Terms

Bit depth: the number of bits per pixel in frame buffer.

Bitmap: the frame buffer with one bit per pixel.

Pixmap: the frame buffer with multiple bits per pixel.

Frame Buffer

- If we want a frame buffer of 640 by 480 pixels, we should allocate:

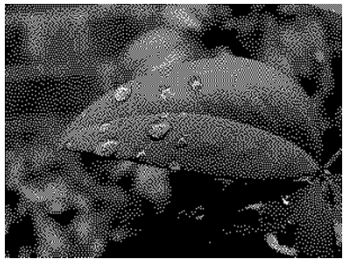
  Pixels in Frame buffer = 640 * 480

- How many bits should we allocate?

  n * 640 * 480, n is the number of bits per pixel

Frame Buffer Bit Depth

- 1 bit per pixel (bitmap)


1-bit

- 16 bits per pixel (high color)
  - 5 bits for red, 5/6 bits for green, 5 bits for blue
  - potential of 32 reds, 32/64 greens, 32 blues
  - total colors: 65536 (2^{16})


8-bit

- 32 bits per pixel (true color)
  - 8 bits for red, green, blue, and alpha
  - potential for 256 reds, greens, and blues
  - total colors: 16777216 (2^{24}: more than the eye can distinguish)


24+ bits

(Pictures from Wiki)

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

Random-Scan Displays

- Vector displays (or stroke-writing displays)

  Using a single gun to draw lines.

  Think of having a VERY FAST drawing pen.

- Advantages:
  - Smooth and brighter lines, usually for line drawing applications
  - Higher resolution than raster scan systems

- Disadvantages:
  - Cannot display realistic shaded scenes

Game: Vectrex
http://www.vectrex.co.uk/

Color CRTs

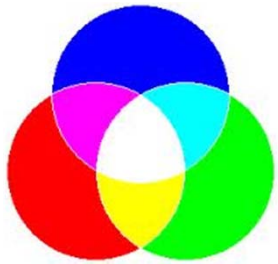
- Color pictures usually produced in CRT monitors by using several kinds of phosphors that emit different-colored light

- Two main methods
  - ***Beam-Penetration method***
  - ***Shadow-mask method***

Color CRTs

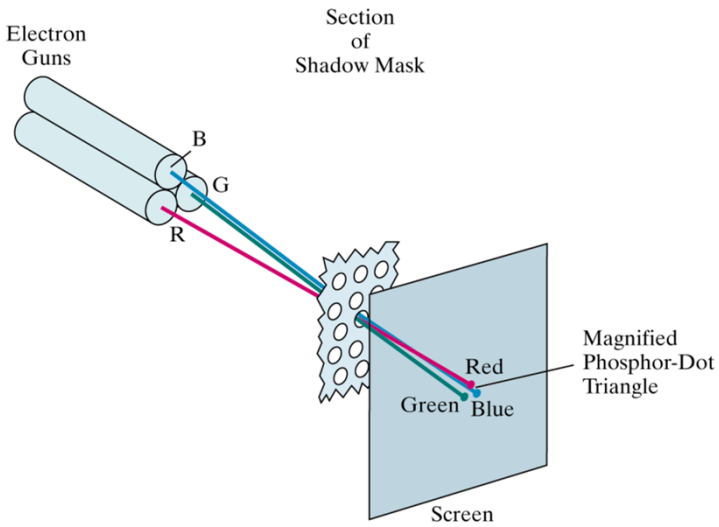
- **Beam-Penetration** Method (for random-scan systems)
  - The CRT screen coated from inside with two layers of phosphor, usually Red and Green.

  - Colors generated depend on how far the electron beam penetrates into the phosphor layers.
    - Red is produced by a slow electron beam;
    - Green color is generated by a very fast electrons penetrates through the red layer and excites the inner green layer;
    - Orange and Yellow are generated by an intermediate beam speeds, as a combination of red and green.
  - Advantages: inexpensive;
  - Disadvantages: a limited number of color; low quality.



Color CRTs

- **Shadow-mask** Method (for raster-scan displays)
  - Generate more colors than the beam-penetration method.
  - Each pixel of the screen is coated with three phosphor color dots, red, green, and blue.



Each electron gun for activating one of the three phosphor color dots.

A shadow-mask grid are placed behind the screen directing the guns to each dot triangle.

CRT HowTo

Flat-Panel Displays

- Advantages:
  - Small Volume.
  - Light Weight.
  - Low Power Consumption.

Flat-Panel Displays

- FPDs are divided into two main categories:

  1. Emissive Displays: convert ***electrical*** energy into light.

  Examples:

  - Plasma panels (等離子體顯示屏)
  - Thin-Film Electroluminescent Displays (薄膜電發光)
  - Light Emitting Diodes (LED:發光二極管)
  - Flat CRTs

  2. Non-Emissive Displays: use ***optical*** effects to convert the light from surroundings or from an internal light source to produce a picture.

  Example: Liquid Crystal Display (LCD)

Liquid Crystal Display

- Glass plates: contain a light polarizer (偏光器)
- Liquid crystal: crystals liquefy when excited by heat or electronic field.
- Liquid crystal can be aligned to either block or transmit the light.
- Image produced by passing polarized light through a liquid-crystal material.

LCD HowTo

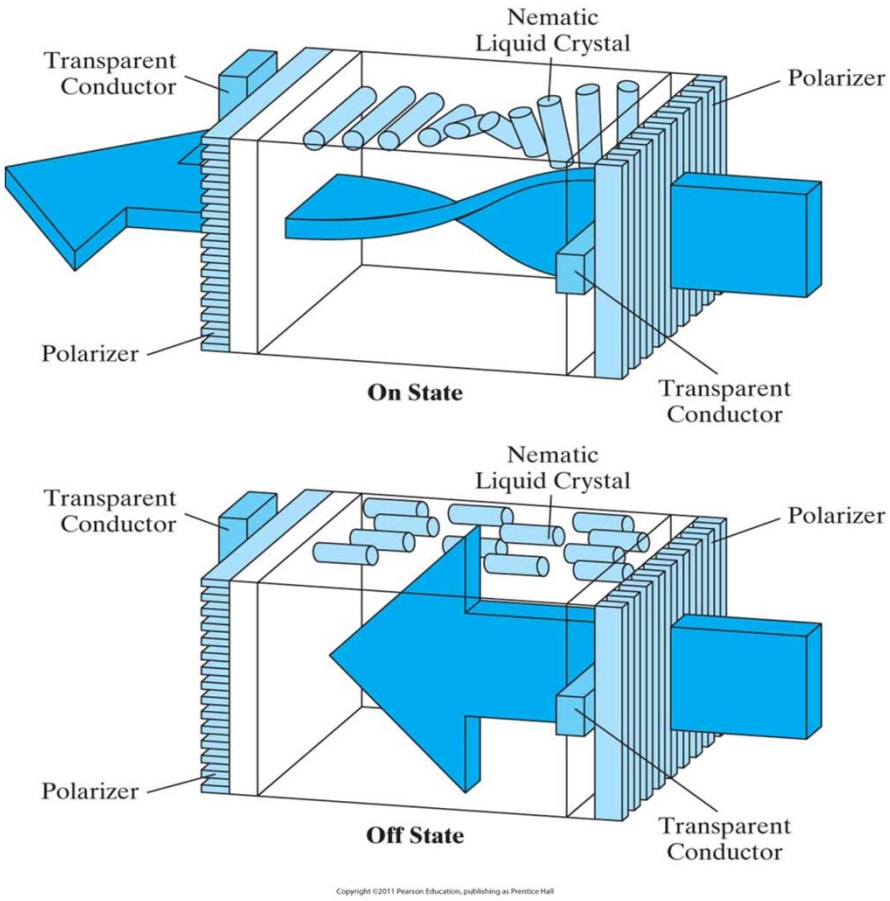


Figure 2-13 The light-twisting, shutter effect used in the design of most LCD devices.

Displays in Virtual Reality

- Head-Mounted Displays (HMDs)
  - The display and a position tracker are attached to the user's head. Two small TV screens are embedded in a rack and placed in front of the two eyes.
  - A track system is used to report the position of HMD 3D space.
  - It allows full-freedom head movement, and gives the feel of immersion.

- Applications of HMDs
  - Portable entertainment, private movie watching
  - PC game
  - Virtual flight simulator

lightweight i-glasses

Example Intro. Video: Virtual Reality Helmet for Flight Simulator

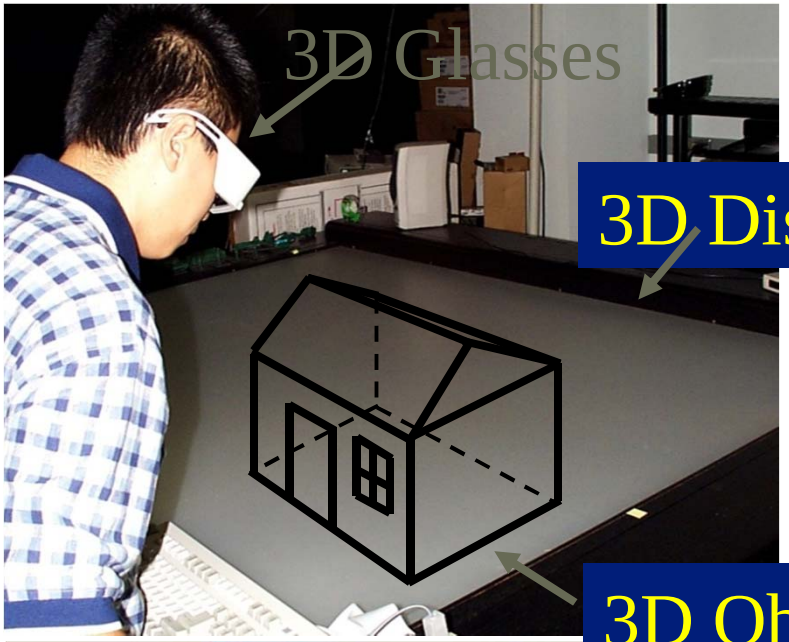
Displays in Virtual Reality

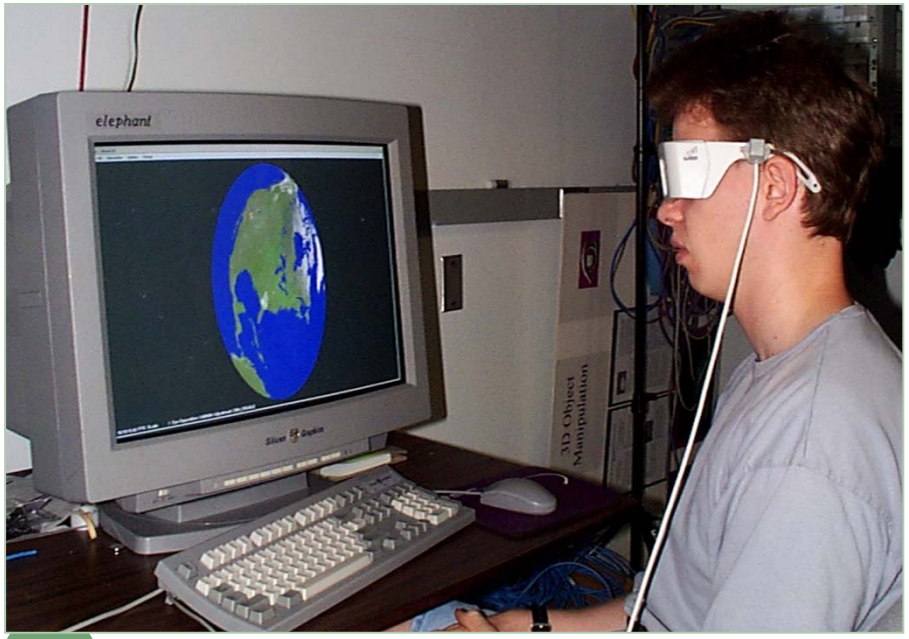
- Head-Tracked Displays (HTDs)
  - Display is stationary, tracker tracks the user's head relative to the display.
  - Example: CAVE, Stereo monitor

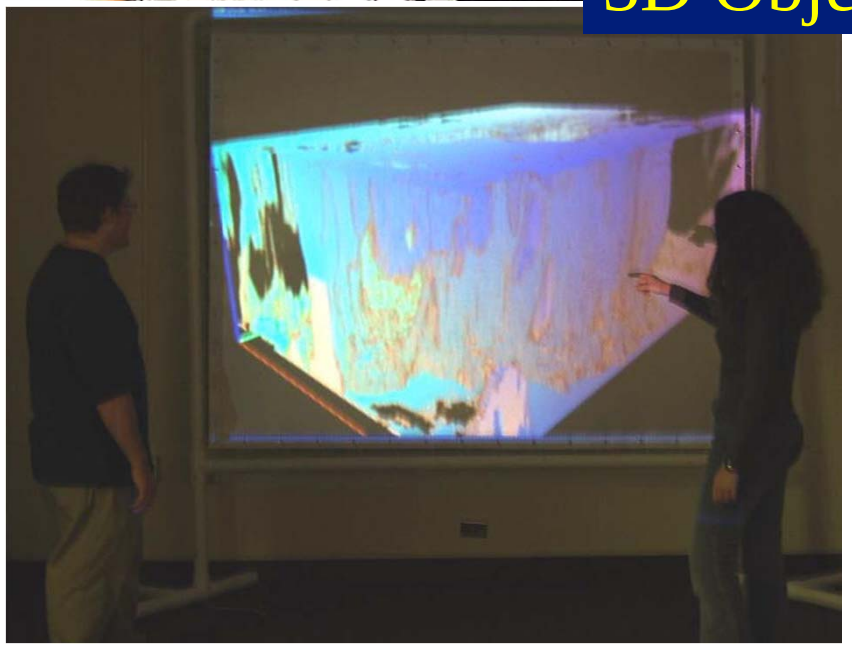
(The CAVE, from Wiki)

Birth of CAVE: Pocket Cathedral (1991)

  - Stereoscopic viewing glasses
    - Users wear them to perceive the stereoscopic view of 3D scenes displayed on the screen


3D Glasses
3D Display
3D Object


elephant
3D Object Manipulation

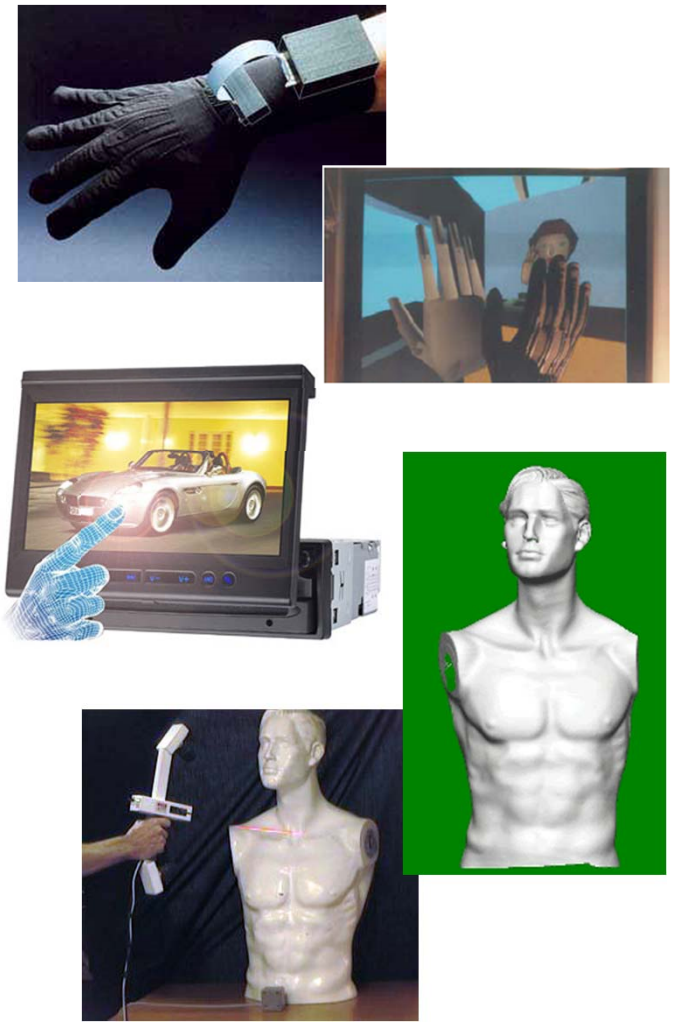


Input Devices

- **Keyboard**
- **Mouse** (2D and 3D)
- **Trackball**: a 2D input device, usually used on a mouse or a lap-top computer.
- **Space ball**: hand held, non-movable. It uses a strain gauge to detect pull, push, and twist applied to the ball, and translate them into 3D locations. Used for navigation in virtual environments, CAD, etc.
- **Head Mounted Display**: Although it is primarily a display device, it can also track position and orientation
- **Joystick**: similar to the space ball. Can be movable and non-movable.

Input Devices

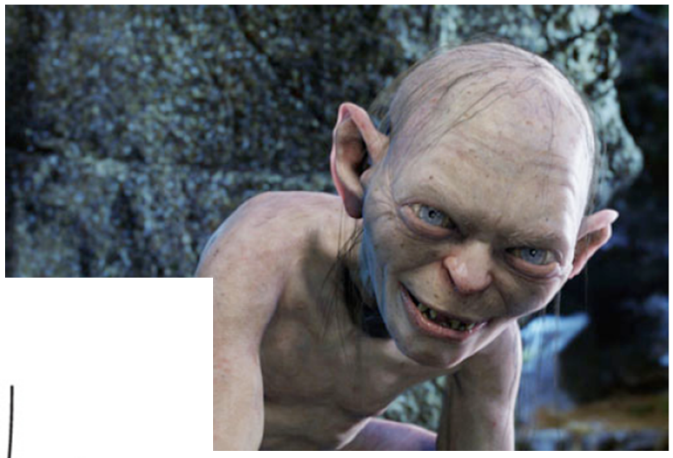
- **Data glove**: a glove with sensors. Used to control a virtual hand for grasping, dropping, and moving an object in a virtual environment.
- **Image scanner**: input still picture, photo, or slides as images into computer.
- **Touch panel**: highly transparent and embedded over a display surface.
- **Digital camera**: directly stores photo shots as images on a diskette.
- **Digital video recorder**: input a video clip in digital form; often used for tele-conferencing.
- **Laser range scanner**: input discrete and scattered points on a 3D surface model from which a digital one can be built.



Input Devices

- **Motion Capture**: input full-body, facial, hand movements

Bring Gollum to Life



[*The Two Towers* | New Line Productions]

Graphics Systems

- Interactive raster-graphics systems naturally use several processing units.
  - **CPU**
  - **Video controller (display controller):** a special-purpose processor, used to control the operation of the display device.

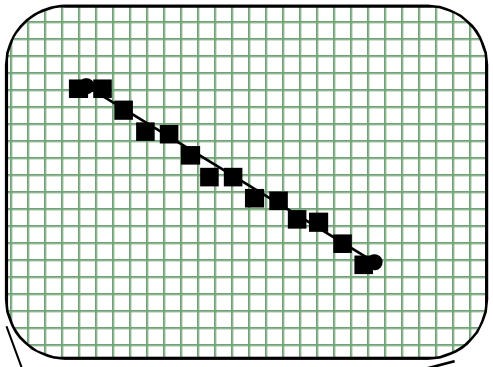
  - A simple raster system
    - Frame buffer can be anywhere in the system memory.
    - The video controller only accesses the frame buffer to refresh the screen.

  (see the figure in the next slide)

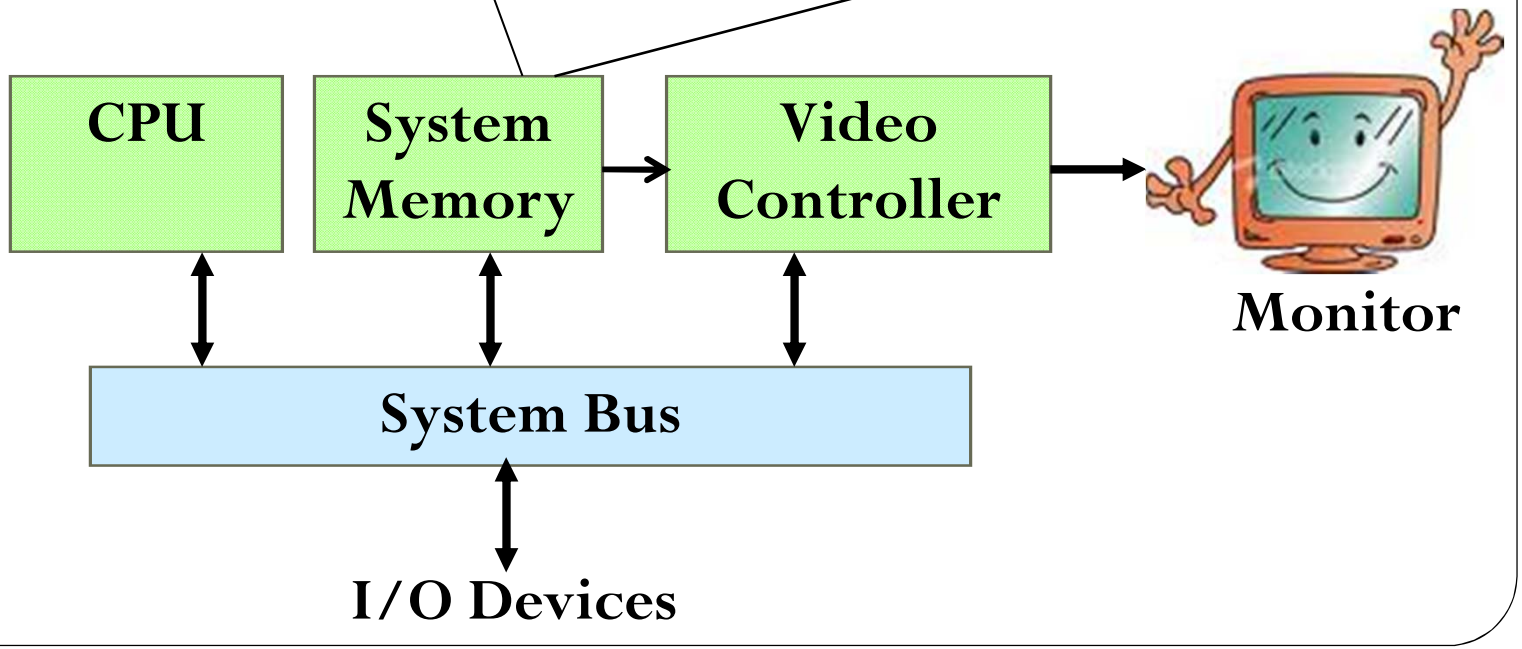
Graphics Systems

- Architecture of a simple raster-graphics system in old days

Video controller just accesses the frame buffer to refresh the screen.

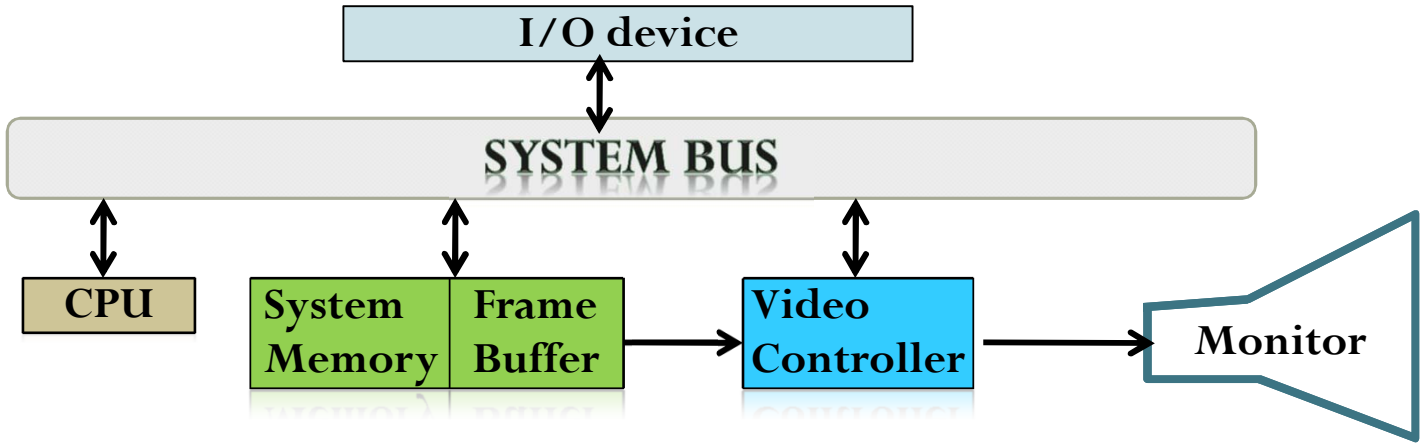


Frame buffer can be anywhere in the system memory.



Graphics Systems

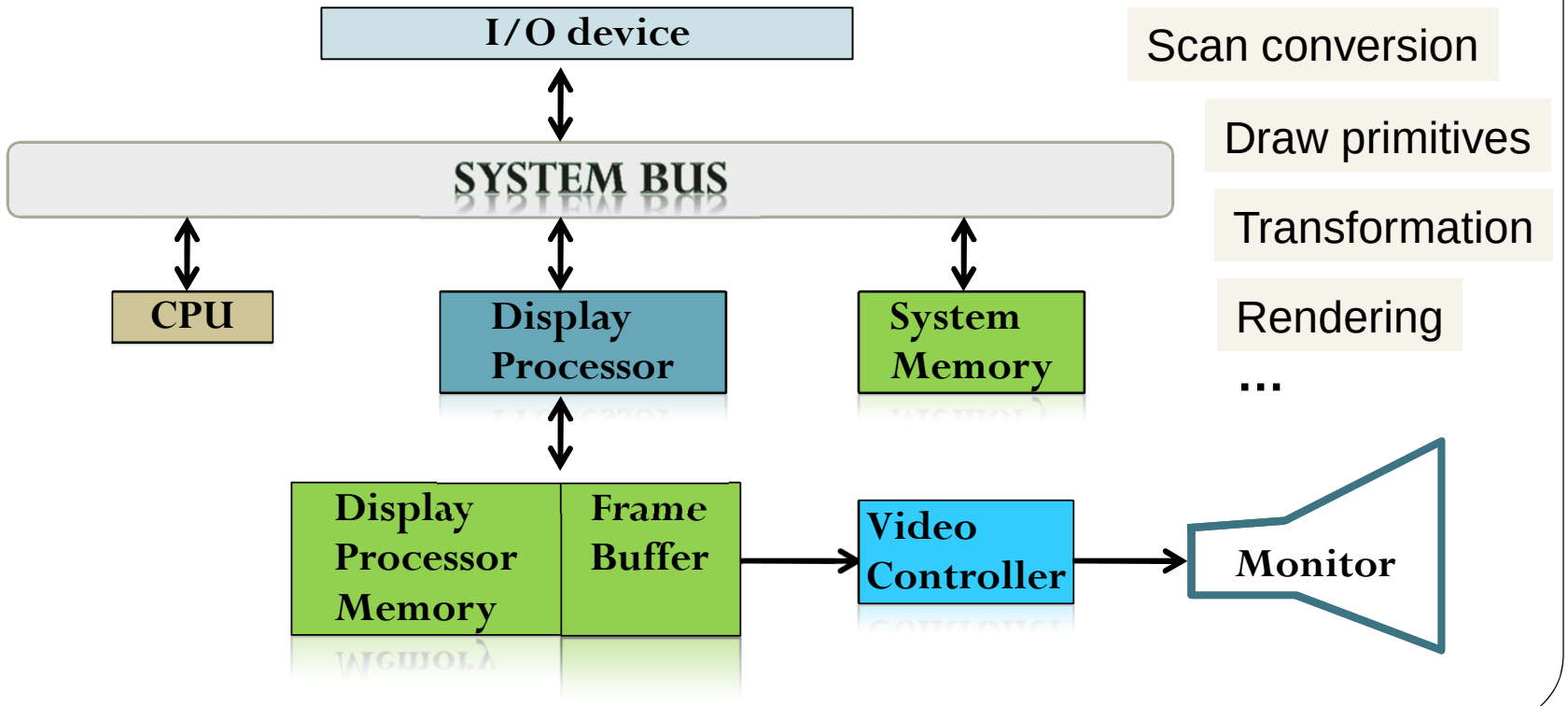
- Architecture of a raster-graphics system with a fixed portion of the system memory for the frame buffer



- Graphics work is done by CPU -- slow
- As refresh cycle increased, memory cycles used by video controller increases – less memory for other work to CPU
- Solution: **Graphics Display Processor**

Raster-Scan Display Processor

- **Graphics controller** (display coprocessor): a separate display processor.
- Purpose: to free the CPU from the graphics work.
- A separate **display-processor memory** area can be supplied.



End of Chapter 2