Overview of Graphics Systems
Agenda

- Video display devices
- Raster-scan systems
- Graphics workstations and viewing systems
- Input devices
Learning Objectives

• Understand which are the important display devices and input devices.

• Understand how the important output devices for computer graphics work.

• Understand how the important input devices for computer graphics work.
Video Display Devices

- Cathode-ray tubes
- Raster-scan displays
- Random-scan displays
- Color CRT displays
Cathode-Ray Tubes

• Classical output device is a monitor.
• Cathode-Ray Tube (CRT)
  – Invented by Karl Ferdinand Braun (1897)
  – 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)
  – Refresh rate (50-60 Hz / 72-76 Hz) to avoid flicker / trail
  – Phosphors are organic compounds characterized by their persistence and their color (blue, red, green).
Cathode-Ray Tubes

(from Donald Hearn and Pauline Baker)
Cathode-Ray Tubes

Figure 2-3
Operation of an electron gun with an accelerating anode.

(from Donald Hearn and Pauline Baker)
Cathode-Ray Tubes

• Cathode-Ray Tube (CRT)
  – Horizontal deflection and vertical deflection direct the electron beam to any point on the screen
  – Intensity knob: regulates the flow of electrons by controlling the voltage at the control grid (high voltage reduces the electron density and thus brightness)
  – Accelerating voltage from positive coating inside screen (anode screen) or an accelerating anode

• Image maintenance
  – Charge distribution to store picture information
  – Refresh CRT: refreshes the display constantly to maintain phosphor glow.
Cathode-Ray Tubes

• Characteristics of Cathode-Ray Tube (CRT)
  – *Intensity* is proportional to the number of electrons repelled in beam per second (*brightness*)
  – *Resolution* is the maximum number of points that can be displayed without overlap; is expressed as number of horizontal points by number of vertical points; points are called pixels (picture elements); example: resolution 1024 x 768 pixels. Typical resolution is 1280 x 1024 pixels.

• High-definition systems: high resolution systems.
Cathode-Ray Tubes

Figure 2-4
Electrostatic deflection of the electron beam in a CRT.

(from Donald Hearn and Pauline Baker)
Cathode-Ray Tubes

• Focusing
  – *Focusing* forces the electron beam to converge to a point on the monitor screen
  – Can be electrostatic (lens) or magnetic (field)

• Deflection
  – *Deflection* directs the electron beam horizontally and/or vertically to any point on the screen
  – Can be controlled by electric (deflection plates) or magnetic fields (deflection coils)
  – Magnetic coils: two pairs (top/bottom, left/right) of tube neck
  – Electric plates: two pairs (horizontal, vertical)
Raster-scan Displays
Raster-scan Displays

- The image is stored in a *frame buffer* containing the total screen area and where each memory location corresponds to a pixel.

- In a monochrome system, each bit is 1 or 0 for the corresponding pixel to be on or off (bitmap).

- The display processor scans the frame buffer to turn electron beam on/off depending if the bit is 1 or 0.

- For color monitors, the frame buffer also contains the color of each pixel (color buffer) as well as other characteristics of the image (gray scale, …). 8 bits/pixel $\rightarrow$ 0..255 (pixmap).

- Depth of the buffer area is the number of bits per pixel (bit planes), up to 24.

- Examples: television panels, printers, PC monitors (99% of raster-scan)…
Raster-scan Displays

- Refresh rate: 24 is a minimum to avoid flicker, corresponding to 24 Hz (1 Hz = 1 refresh per second)
- Current raster-scan displays have a refresh rate of at least 60 frames (60 Hz) per second, up to 120 (120 Hz).
- Uses large memory: $640 \times 480 \rightarrow 307200$ bits $\rightarrow 38$ kB
- Refresh procedure:
  - Horizontal retrace – beam returns to left of screen
  - Vertical retrace – beam 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).
Move(2,0)  
Line(4,4)  
Move(-4,0)  
Line(4,-4)

commands in display list

frame buffer

screen after 1 scan lines

screen after 2 scan lines

screen after 3 scan lines

screen after 4 scan lines

screen after 5 scan lines
Raster-scan Displays - Architecture
Random-scan Displays
Random-scan Displays

- Random scan systems are also called vector, stroke-writing, or calligraphic displays.
- The electron beam directly draws the picture in any specified order.
- A pen plotter is an example of such a system.
- Picture is stored in a display list, refresh display file, vector file, or display program as a set of line drawing commands.
- Refreshes by scanning the list 30 to 60 times per second.
- More suited for line-drawing applications such as architecture and manufacturing.
Random-scan Displays

- **Advantages:**
  - High resolution
  - Easy animation
  - Requires little memory

- **Disadvantages:**
  - Requires intelligent electron beam (processor controlled)
  - Limited screen density, limited to simple, line-based images
  - Limited color capability.

- **Improved in the 1960’s by the Direct View Storage Tube (DVST) from Tektronix.**
Images are described in terms of line segments rather than pixels.
Random-scan Displays - Architecture

- CPU
- System Memory
- Display Processor
- System Bus
- I/O Devices
- Monitor
Raster-scan vs. random-scan
Color CRT Monitor

- Color CRT’s are designed as RGB monitors also called full-color system or true-color system.
- Use shadow-mask methods with intensity from each electron gun (red, green, blue) to produce any color directly on the screen without preprocessing.
- Frame buffer contains 24 bits per pixel, for 256 voltage settings to adjust the intensity of each electron beam, thus producing a choice of up to 17 million colors for each pixel ($256^3$).
Color CRT Monitor

(from Donald Hearn and Pauline Baker)
A *workstation* is a computer designed for technical or scientific applications. Intended primarily to be used by one person at a time, they are commonly connected to a local area network and run multi-user operating systems.
INPUT DEVICES
The key matrix
This keyboard uses rubber dome switches.
Optimus keyboard programmable
hot keys
Buttons
Dials
Trackball
Spaceball
Joysticks / Mice / Trackballs
Data Glove
Digitizer Tablet (Data Tablet)
Digitizer used for drawing larger Images
Voice Systems