Overview of Graphics Systems

Agenda

- Video display devices
- Raster-scan systems
- Graphics workstations and viewing systems
- Input devices
- Hard-copy 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
- Flat-panel displays
- Three-dimensional viewing devices
- Stereoscopic and virtual-reality systems
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 < 1ms 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

- 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 (from Donald Hearn and Pauline Baker)

- **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, slide 9) or magnetic fields (deflection coils, slide 5)
  - Magnetic coils: two pairs (top/bottom, left/right) of tube neck
  - Electric plates: two pairs (horizontal, vertical)

Cathode-Ray Tubes

- **Aspect ratio**
  - *Aspect ratio* is the ratio of horizontal pixels to vertical pixels for an equal length line.
  - It is the ratio of the horizontal dimension over the vertical dimension.
Cathode-Ray Tubes

(from SIGGRAPH)

If resolution of 640 x 480 pixels:

- Horizontal: 640/8 = 80 pixels / inch
- Vertical: 480/6 = 80 pixels / inch

Square pixels (no distortion).

Raster-scan Displays

- Video displays can be either raster-scan or random-scan displays.
- Raster-scan display is the most common type of monitor using a CRT.
- The electron beam scans the screen from top to bottom one row at a time. Each row is called a scan line.
- The electron beam is turned on and off to produce a collection of dots painted one row at a time. These will form the image.
- A raster is a matrix of pixels covering the screen area and is composed of raster lines.

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: 640x480 → 307200 bits → 38 kB
- 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).

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.

Color CRT Monitor

- Uses different phosphors, a combination of Red, Green, and Blue, to produce any color.
- Two methods:
  - Random scan: uses beam penetration.
    2 layers (Red, Green) phosphors; low speed electrons excite Red, high speed electrons excite Green, intermediate speed excite both to get yellow and orange. Color is controlled by electron beam voltage.
    Only produces a restricted set of colors.
  - Raster scan: uses a shadow mask with three electron guns: Red, Green, and Blue (RGB color model). Color is produced by adjusting the intensity level of each electron beam.
    Produces a wide range of colors, from 8 to several millions.
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 ($256^3$).

Flat Panel Displays

- Flat panel displays are video devices that are thinner, lighter, and require less power than CRT’s.
- Examples: wall frames, pocket notepads, laptop computer screens, …
- Emissive versus non-emissive:
  - Emissive panels convert electrical energy into light: plasma panels, thin-film electroluminescent display device, light-emitting diodes.
  - Non-emissive convert light into graphics using optical effects: liquid-crystal device (LCD).
Flat Panel Displays

• Plasma-panel display:
  a mixture of gases between two plates
  vertical conducting ribbons are placed in one plate, and
  horizontal conducting ribbons are placed in the other
  plate
  voltage is applied to the two ribbons to transform gas
  into glowing plasma of electrons and ions.

Flat Panel Displays

• Thin-film electroluminescent display:
  similar devices except that the region between the plates
  is filled with phosphor instead of gas.
  
  Example: zinc sulfide with manganese
  voltage applied between the plates moves electrons to
  the manganese atoms that release photons of light.
Flat Panel Displays

• Light-emitting diode:
  a matrix of diodes, one per pixel
  apply voltage stored in the refresh buffer
  convert voltage to produce light in the display.

Flat Panel Displays

• Liquid-crystal displays (LCD):
  LCD screens are often used in small devices such as calculators
  and laptop monitors.
  non-emissive.
  picture produced by passing light from a light source through
  liquid-crystal material
  liquid-crystal material can be programmed to either let the light
  through or not
  liquid-crystal material contains crystals within a liquid
  nematic (thread-like) liquid-crystals have rod shape that can either
  align to with the light direction or not
  (when voltage is applied to conductors) panel made of rows of horizontal, transparent conductors
  apply voltage to two ribbons to make plasma glow
  two polarizers, two conductors, reflector

(from Donald Hearn and Pauline Baker)
Three-Dimensional Viewing Devices

- For the display of 3D scenes.
- Often using a vibrating, flexible mirror.
- Scan alternate images in alternate frames.
- Multiple stereo images (time multiplexing).

Stereoscopic and Virtual-Reality Systems

- Another technique for the display of 3D scenes.
- Not true 3D images, but provides a 3D effect.
- Uses two views of a scene along the lines of right and left eye. Gives perception of a scene depth when right view is seen from right eye and left scene is seen from left eye (stereoscopic effect). Display each view at alternate refresh cycles.

Stereoscopic and Virtual-Reality Systems

- Stereoscopic systems are used in virtual reality systems:
  - Augmented reality
  - Immersive reality
    - Headset generates stereoscopic views
    - Input devices (gloves, helmet, …) capture motion
    - Sensing system in headset tracks user’s position
- Scene projected on an arrangement of walls

Graphics Workstations

- Graphics monitors use raster-scan displays (CRT or flat-panel monitors).
- Graphics workstations provide more powerful graphics capability:
  - Screen resolution 1280 x 1024 to 1600 x 1200.
  - Screen diagonal > 18 inches.
- Specialized workstations (medical imaging, CAM):
  - Up to 2560 x 2048.
  - Full-color.
- 360 degrees panel viewing systems.
Input Devices

- Input devices
  - Keyboards, button boxes, dials
  - Mouse devices
  - Trackballs and spaceballs
  - Joysticks
  - Data gloves
  - Digitizers
  - Image scanners
  - Touch panels
  - Light pens
  - Voice systems

Input Devices

- Keyboards, button boxes, dials
  - Standard keyboard
    - Alphanumeric
    - Function keys
  - Button box
    - set of input dials

Input Devices

- Mouse devices
  - Mechanical mouse
    - One-button
    - Rotating ball
    - Two perpendicular shafts to capture rotation
  - Optical mouse
    - Optical sensor
    - Laser
    - Grid to detect movement
  - Added widgets
    - Buttons
    - Trackball
    - Thumbwheel.

Input Devices

- Trackball
  - A ball device that can be rotated with the fingers or palm of hand

- Spaceball
  - Six degrees of freedom
  - Does not move, detects strain placed on the ball by trying to move it.
Input Devices

- Joystick
  - A small, vertical lever mounted on a base
  - Movable joystick measures motion
  - Stationary (isometric) joystick measures strain.

- Data glove
  - Used to grasp a virtual object
  - Measures hand and finger position
  - 2D or 3D
  - Can also be used as input device to detect surface.

Input Devices

- Digitizers
  - Used for drawing, painting, or selecting positions
  - Graphics tablet used to input 2D coordinates by activating a hand cursor or stylus at given positions on a flat surface
  - Used to trace contours, select precise coordinate positions
    - Hand held cursor
    - Stylus
  - Electromagnetic
    - Grid of wires
    - Electromagnetic pulses send an electrical signal in stylus or cursor
  - Acoustic
    - Sound waves to detect stylus position by microphones
    - Can be 3D

Input Devices

- Image scanners
  - Used to store images on a computer
  - Hand held
  - Flatbed
  - Drum.

Input Devices

- Touch panels
  - Select objects by the touch of a finger
  - Optical
    - Line of infrared light-emitting diodes (LED) along vertical and horizontal edges
    - Interrupted when panel is touched
  - Electrical
    - Two transparent plates of material, one conducting, the other resistive
    - Touch brings the plates to be in contact with one another, causing a voltage drop
    - Measure the voltage drop
  - Acoustical.
Input Devices

• Light pens
  – Pen-shaped device to select screen positions by
detecting lights coming from points on the CRT screen
  – Used to capture position of an object or select menu
options.

Input Devices

• Voice systems
  – Speech recognition systems to recognize voice
commands
  – Used to activate menu options or to enter data
  – Uses a dictionary from a particular user (learning
system).

Hard-copy Devices

• Hard-copy devices
  – Plotters
    • 2D moving pen with stationary paper
    • 1D pen and 1D moving paper
  – Printers
    • Impact devices
      – Inked ribbon
    • Non impact devices
      – Laser, ink-jet, xerographic, electrostatic, electrothermal.