Computer Graphics Hardware

- Output Devices
  - Display
    - Vector
    - Rastor
  - Hardcopy
    - Plotters
    - Printers
- Input Devices
- Graphics Processors

Video Display Devices

Video Monitor

CRT (cathode ray tube) was most common

- Storage CRT versus Refresh CRT
  - Draw once and image remains on screen
  - Constant refreshing of screen
    - Refresh rates - 30 Hz, interlaced

Basic CRT design

- (see figure)
- Vacuum in a glass tube
- Electron gun
- Cathode with coiled wire filament
  - heat and it emits electrons
  - very high voltages
- Deflection system
- Phosphor coated screen

- Focusing system

- Acceleration system

Focusing system
- electrons repel each other - diverge
  - a) Magnetic
    - coil around outside of tube
    - very small spot size
    - flying spot scanners
  - b) Electrostatic
    - most common in graphics monitors
    - positively charged metal cylinder
      - (electrostatic lens)
- focuses beam in middle of screen
  - curved screen
    - distance from "lens" to screen is constant
  - flat screen
    - distances increase from center
    - additional electronic deflection dependent focusing
      - (see figure)

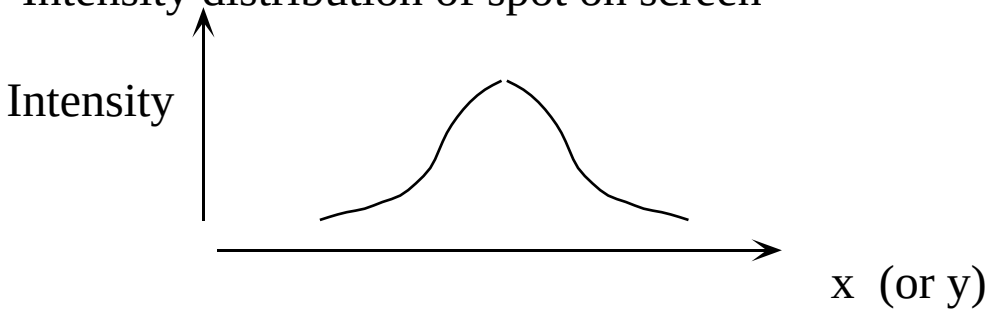
Acceleration system
- Speed electron towards the screen
  - a) Positively charged metal near screen
  - b) Accelerating anode
    - (see figure)

Deflection system
- Control where beam hits screen
  - a) Magnetic deflection
    - 2 pairs of coils mounted outside envelope
      - top and bottom
      - right and left
    - vary currents in coils to get correct deflection
    - most common
    - (see figure)
  - b) Electrostatic deflection
    - 2 pairs of plates inside envelope
    - vary charge
    - (see figure)

Screen
- coated with phosphors
- electrons hit screen and loose energy
  - heat
  - most goes to electrons of phosphor
    - jumps them to higher energy states
    - when fall back to lower states - give off energy as light
- Phosphor characteristics
  - color of light - wavelength of energy
  - persistence
    - time taken to go from initial light level to 1/10th
    - long persistence
      - refresh less frequently
      - what happens to image of moving objects?
    - short persistence
      - refresh more frequently
      - less motion blur
      - typical 10 - 60 microseconds

Intensity
- Control grid of electron gun
  - the more negatively charged, more electrons get repelled
    - the fewer make it through the control grid

Intensity distribution of spot on screen



- Gaussian fall off of intensity with distance
- Function of the electron density in the beam

Resolution

Maximum number of dots that can be displayed without overlap

on CRT

(1K by 1K)

independent of screen size

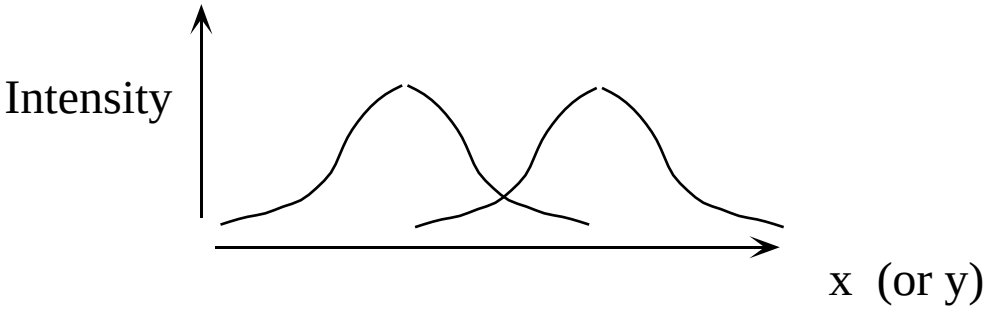
OR

Maximum number of dots that can be displayed per inch or cm

(300 dpi)

How define overlap?

okay to overlap portions falling below 60% of maximum



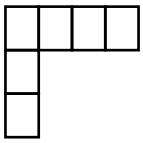
What happens to overlap as increase intensity?

Aspect ratio

ratio of number of vertical points to horizontal points to

produce equal length lines

3/4



Rastor Scan versus Random Scan

(see figures)

Random scan

refresh is a function of the image complexity

Rastor scan

horizontal retrace and vertical retrace

interlaced versus noninterlaced

- Refresh rate
  - 60 hz is typical
    - how often refresh each "dot" on screen?
      - once every 16667 microseconds
    - compare to persistence (10-60 microseconds)
    - "dot" is mostly dark!
  - flicker
    - when image appears to go on and off
    - refresh rate not high enough
  - CFF - critical fusion frequency
    - freq at which flickering display just fuses into nonflickering
    - what determines CFF?
      - for given phosphor?
- Horizontal scan rate
  - scan lines displayed per second
  - approximately refresh rate times number of lines

- Color CRTs
  - Beam penetration
    - Random scan
    - two layers of phosphor
      - slow beam - outer layer (say red)
      - faster beam - inner layer (say green)
  - Shadow mask
    - more colors
    - better quality
    - small patches of red, green and blue phosphors
      - perceive as one colored patch
    - 3 electron guns
    - a) delta-delta
      - triad of patches
      - (see figure)
      - shadow mask
      - difficult to keep aligned
      - high resolution
    - b) precision in-line
      - easier to align, lower resolution

Flat-Panel Displays
- Thinner, lighter, require less power
- Examples?

- Emissive versus nonemissive
  - Can you see it in the dark?
  - Could be lighted nonemisive

  - Emissive
    - Plasma panels
      - mixture of gases between two glass plates
      - vertical and horizontal conducting ribbons
      - apply voltage to two ribbons to make plasma glow
      - (see figure)
    - Thin-film electroluminescent displays
      - similar, but phosphor instead of gas
      - (see figure)
    - LED's
      - matrix of diodes, one per pixel
      - apply voltage and they produce light
  - Nonemissive
    - LCD
      - LC substance flow like a liquid, but have crystaline molecular structure
      - Usually use nematic LC's (threadlike)
      - Two polarizers, two conductors, reflector
      - LC in normal state twists the light, so is reflected back to viewer
      - apply voltage to conductors to turn off (see figure)
      - Active Matrix LCD - transistor at each pixel (stores)

Projection CRT

project light from small diameter, very bright CRT onto screen

(example?)

LCD Projection

flat panel display used with overhead projector

(see figure)

3D Viewing

Stereoscopic viewing

Stereo images (not full 3-d)

a) Red and green glasses

red and green images

b) Scan alternate images in alternate frames

View with goggles that shutter each lens in synch with scanning

(see figures)

c) Multiple stereo images versus just two

Time Multiplexing

As rotate head, see different views

Compare to 2 view perception as move head

Hard Copy Output Devices
- Plotters
- Printers

- Impact Devices
  - Inked ribbon
  - examples?

- Nonimpact Devices
  - Lasers, ink-jets, xerographic, electrostatic, electrothermal
  - examples?

- Pen plotters
  - Stationary paper and 2-D moving pen
    - (see example)
  - Paper moves in 1-D and pen in 1-D
    - (see example)
  - Resolution issues
    - Random Scan or Raster Scan?
    - How draw line?
      - What determines resolution along length of line?
      - What determines resolution across width of line?

- Dot Matrix Printers
  - Print head with matrix of wire pins
  - Retract some pins before printing to print specified pattern

- Laser Printers
  - Drum coated with photoelectric material (eg selenium)
  - Laser beam creates charge distribution on drum
  - Toner applied to drum and sticks according to charge
  - Toner transferred to paper

Ink-Jet Printers
- Paper rolled on drum
- Boiled ink squirted onto paper through little nozzles (jets)
- Charged ink stream deflected by electric field
- (see figures)

Electrostatic Printers
- Negatively charge a row at a time on paper
- Apply toner
- (see figure)

Electrothermal Printer
- Heat sensitive paper
- Dot matrix print head applies heat
- (example?)

Dye Sublimation

How get color output?

Impact device?

Non impact device?
- 3 pigments: cyan, magenta, yellow (sometimes black)

Will you get the same colors on a laser printer, as on a CRT?

Non Hard Copy , Non Display Output Devices

Print 3-D solid objects
- Ink jet like head
- Squirts fast drying thermopolymer material
- Builds up 3-D models in layers

Input Devices

Keyboards

- Standard Keyboard
- Button Boxes
  - (see example)

Mouse

- Mechanical mouse
  - Rotating ball
  - Two perpendicular padded shafts rotated by ball motion
    - shaft encoders output proportional to rotation
- Optical mouse
  - Laser
  - Reflective Grid
- Added buttons, trackball, thumbwheels

Trackball

- Like upside down mouse with big ball
- Fingers or hand move ball

Joystick

- Movable
  - Measure motion
- Stationary
  - Measure strain

Data Glove

- Measures hand position and uses as input
- Many degrees of freedom

(aside - data glove as output device
- haptic computer interface
- texture and pressure sensation via forces applied
  - to finger tip
- (see example))

Motion Capturing Systems

- Selspots
  - Attached to body in motion
  - Capture 3-D paths of points
  - (see example)
  - Occlusion of visual "spots"
- Full Body Scanners
  - How does it work?
  - (see example)
  - Captures shape and color in 12 seconds
- Uses?

Digitizers

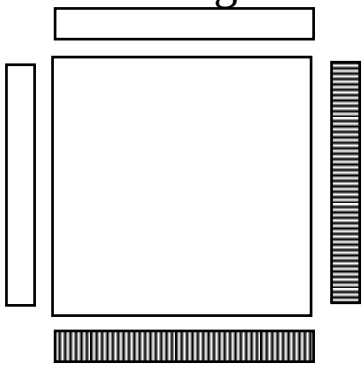
- Graphics Tablets
  - (see example)
  - High resolution input
  - Trace contours
    - Hand held cursor
    - Stylus
    - (see example)
  - Electromagnetic
    - Grid of wires
    - Electromagnetic pulses generated in sequence
    - Induces electrical signal in stylus or cursor
  - Acoustic
    - Strip microphones
    - Detect sound of spark on stylus tip
    - Time arrival at different microphones
  - Can be 3-D
    - (see example)

Image Scanners

- Hand Held
  - (see example)
- Flat Bed
  - (see example)
- Drum
  - (see example)

Touch Panels

- Optical
  - Line LED's along top and side
  - Line of light detectors along bottom and other side



What determines Resolution?

(see example)

- Electrical
  - One plate of conducting material
  - One plate of resistive material
  - Touch pushes plates together
  - Measure voltage drop across resistive plate

- Acoustical

Built into plasma panels

Transparent overlay on other displays