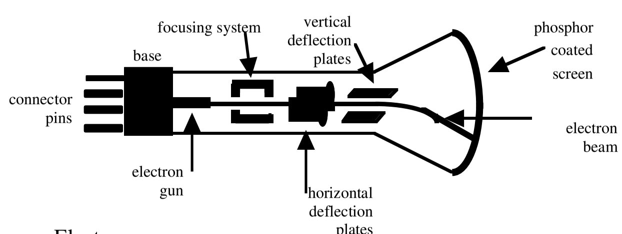
Lecture Notes #1 - Display Hardware

- Readings
  - Angel 1.2-1.4
  - Foley et al., Sections 1.5, 4.2 -- 4.5, 13.2.1, 13.2.2, 13.3.1
- Optional
  - I.E. Sutherland. Sketchpad: a man-machine graphics communication system. *Proceedings of the Spring Joint Computer Conference*, 329-- 346, 1963.
  - T.H. Myer and I.E. Sutherland. On the design of display processors. *Communications of the ACM* 11(6): 410 -- 414, 1968.

History

- Sketchpad -- 1963, Ivan Sutherland
  - constraint-based
  - object-oriented
  - interaction techniques for choosing, pointing, drawing
  - data structures for replicating components
  - beginning of modern interactive graphics

Cathode ray tubes (CRTs)

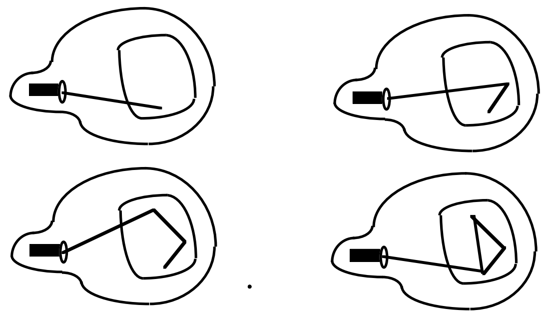


- Electron gun
- Electron focusing lens
- Horizontal and vertical deflection amplifiers
- Electron beam
- Anode (phosphor coating)

CRTs, cont.

- Brightness comes from
  - fluorescence (fraction of microsec)
  - phosphorescence (10 -- 60 microsecs)
- Different phosphors have different
  - colors
  - persistence
- Image needs to be **refreshed** to avoid **flicker**
  - typically, need at least 60Hz
  - exact number depends on: image intensity, ambient lighting, wavelength, size of screen, observer,...

Calligraphic displays



- **Calligraphic display**
- **Vector display**
- **Stroke display**
- **Random scan display**

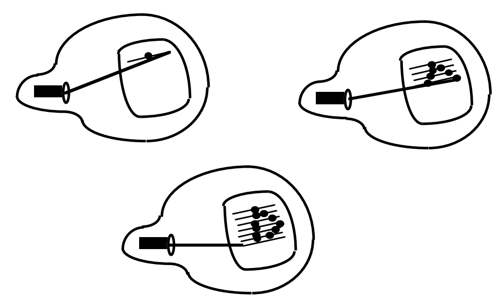
Calligraphic displays, cont.

- Used for example by:
  - Sutherland's Sketchpad
  - Asteroids video game
  - Tempest video game

Raster displays

- History:
  - Developed by Dick Shoup -- early 70's, Xerox PARC
  - Based on TV technology
  - Has had huge impact on computer graphics

Raster displays, cont.



- Electron beam traced in **raster scan order**
- Each left-to-right trace called a **scan line**
- Intensity of beam modulated according to **framebuffer** contents
- Each element of framebuffer associated with a **pixel** on the screen

Grayscale Images

Pixel

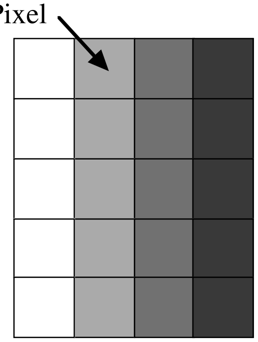


Image (on screen)

255	150	75	0
255	150	75	0
255	150	75	0
255	150	75	0
255	150	75	0

Frame Buffer

Resolution

- **Resolution** is measured in terms of
  - number of scan lines
  - number of pixels per scan line
  - number of bits per pixel
- Examples:
  - TV has around 478 scan lines
  - High res monitors are 1024 x 1280
  - Framebuffers may have 1, 4, 8, 24 or even 96 bits/pixel

Note: Framebuffers require lots of memory -- e.g.,

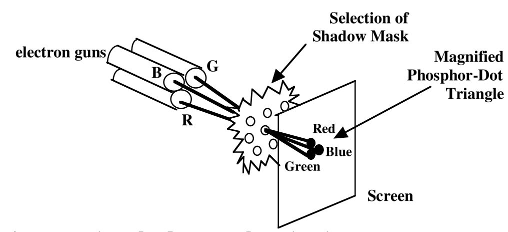
1024 x 1280 x 24 is about 3 megabytes!

Calligraphic vs. Raster Displays

Calligraphic

Raster

Color CRT monitors

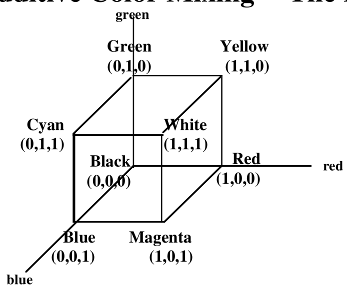


Most color monitors employ **shadow mask** technology

- Uses triads of red, green and blue phosphors at each pixel
- Uses three electron guns, one for each color
- Uses **shadow mask**

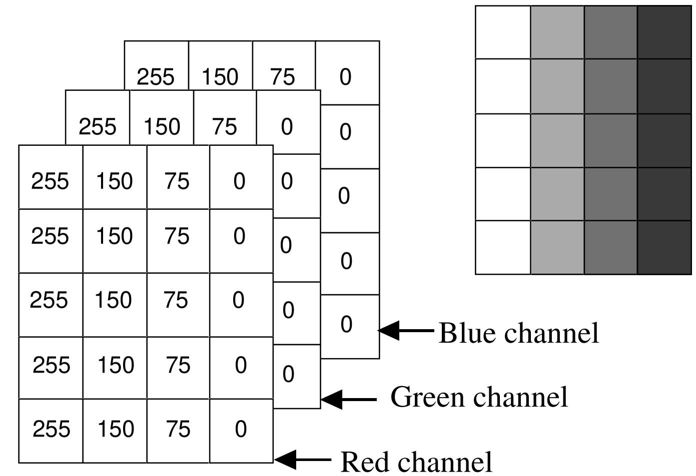
Such CRTs are also known as **RGB monitors**

Additive Color Mixing -- The RGB Cube



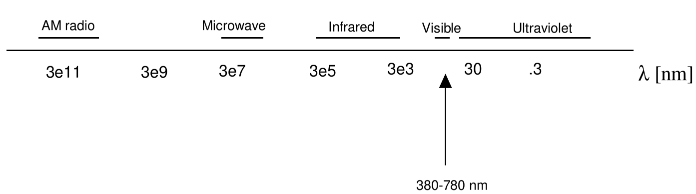
- All colors on a monitor are produced using combinations of red, green and blue.
- A monitor that allows 256 voltage settings for each of R,G, B is known as a **full color system.**
- The description of each color in framebuffer memory is known as a **channel.**

Color Images



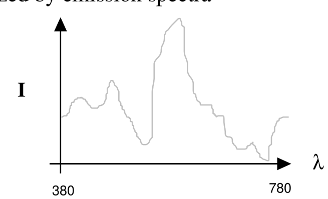
Light

- Light is electromagnetic radiation
- EM spectrum organized by wavelength



Light Sources

- Characterized by emission spectra



- Spectrum describes the energy at each wavelength.
- Light is "infinite dimensional"
  - It takes an infinite number of values to specify an emission spectrum.

Color

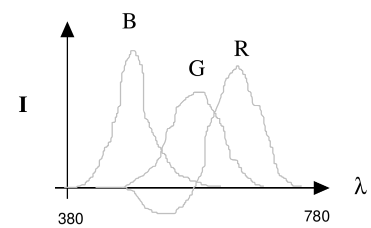
Light ≠ Color

Many different spectra are perceived by humans as the same color.

Two spectra perceived as the same color are called "metamers".

Wright's Experiment

- In the late '20s Wright found that any **spectral** color X could be reproduced with combinations of three primaries at 650 (R), 530 (G), 460 (B) nm.



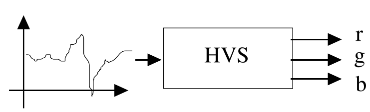
RGB color matching functions

A spectral color is the color perceived due to emission at a single wavelength.

Q: How to get negative red?

Tristimulus Color Theory

- Wright's experiment led to tristimulus color theory.
- States that the human visual system maps each spectrum to three numbers.



- Color space is therefore three dimensional.