Display Devices

Reading


Optional


Light Gathering

The human retina

• Photomicrographs at increasing distances from the fovea. The large cells are cones; the small ones are rods.
Perceptual light intensity

- We perceive light intensity as we do sound: on a relative or logarithmic scale.
- **Example:** The perceived difference between 0.20 and 0.22 is the same as between 0.80 and ______.
- Ideally, to display \( n+1 \) equally-spaced intensity levels

\[
\frac{l_1}{l_0} = \frac{l_2}{l_1} = \ldots = \frac{l_n}{l_{n-1}}
\]

Noise

- **Noise** can be thought of as randomness added to the signal.
- The eye is relatively insensitive to noise.

Lightness contrast

- A related phenomenon is known as:
  - lightness contrast
  - simultaneous contrast
  - color contrast (for colors)
- This phenomenon helps us maintain a consistent mental image of the world, under dramatic changes in illumination.

Light as Waves

- We can think of light as waves, instead of rays.
- Wave theory allows a nice arrangement of electromagnetic radiation (EMR) according to wavelength:
Photopigments are the chemicals in the rods and cones that react to light. Can respond to a single photon!

- Cones come in three varieties: S, M, and L.

Illustration of Color Appearance

Cathode ray tubes (CRTs)

- Consists of:
  - electron gun
  - electron focusing lens
  - deflection plates/coils
  - electron beam
  - anode with phosphor coating

CRTs, cont.

- Electrons “boil off” the heated cathode and shoot towards the anode. Electrons striking the phosphors create light through:
  - fluorescence (fraction of usec)
  - phosphorescence (10 to 60 usec)

- Different phosphors have different:
  - color
  - persistence (as long as a few seconds)

- The image must be refreshed to avoid flicker:
  - typically need at least 60 Hz (why 60 Hz?)
  - exact frequency depends on:
    - persistence
    - image intensity
    - ambient lighting
    - wavelength
    - observer
Raster displays

Electron beam traces over screen in raster scan order.
- Each left-to-right trace is called a scan line.
- Each spot on the screen is a pixel.
- When the beam is turned off to sweep back, that is a retrace, or a blanking interval.

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 per color
- shadow mask used to make each kind of phosphor only “visible” from one gun
These are also known as RGB monitors.

Color CRT monitors, cont’d

A competing technology is called Trinitron (by Sony):
- uses vertical stripes of red, green, and blue phosphors at each pixel
- uses three electron guns, one per color
- uses an aperture grille to make each kind of phosphor only “visible” from one gun
CRT Drawbacks

- Moire patterns result when shadow-mask and dot-pitch frequencies are mismatched
- Convergence (varying angles of approach distance of e-beam across CRT face)
- Limit on practical size (< 1 meter)
- Spurious X-ray radiation
- Occupies a large volume

Liquid Crystal Displays

Laptops typically use liquid crystal displays (LCD’s).
- Light enters a vertical polarizer
- Nematic crystal twists light based on applied voltage (more voltage, less twisting)
- Light passes through horizontal polarizer

Liquid Crystal Displays

Passive matrix displays use a matrix of electrodes to control the voltages. Problem: slow to switch, overflows.

Active Matrix Displays

- Active matrix displays have a transistor at each cell. They use a faster switching crystal and transistors that hold charge and prevent overflow.
- Color filters are used to get color display.
Plasma Displays

- Large format displays (pixels ~1mm compared to 0.2mm for CRT)
- Large viewing angle
- Basically fluorescent tubes

Organic LED Displays

- Self-emissive
- Use of flexible substrates
- Wide viewing angle
- Ultrathin
- Low weight

Resolution

- The display’s **resolution** is determined by:
  - number of scan lines
  - number of pixels per scan line
  - number of bits per pixel

Examples:

- Bitmapped display: 960 x 1152 x 1b, 1/8 MB
- NTSC TV: 640 x 480 x 16b, 1/2 MB
- Color workstation: 1280 x 1024 x 24b, 4 MB
- Laser-printed page:
  - 300 dpi: 8.5 x 11 x 300² x 1b, 1 MB
  - 1200 dpi: 8.5 x 11 x 1200² x 1b, 17 MB
- Film: 4500 x 3000 x 30b, 50 MB
Framebuffers

Intensity of the raster scan beam is modulated according to the contents of a framebuffer.
Each element of the framebuffer is associated with a single pixel on the screen.

Additive color mixing

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, and B is known as a full-color system.
The description of each color in framebuffer memory is known as a channel.

Specifying colors

• The number of color choices depends on the amount of framebuffer storage allocated per pixel.
• 16 bpp systems often allocate 5 bits to red, 6 to green, and 5 to blue. Why does green get the extra bit?

RGB framebuffer

The term true-color is sometimes used to refer to systems which the framebuffer directly stores the values of each channel.
Color tables

- **Color tables** allow more color versatility when you only have a few bits per pixel. You get to select a small **palette** of from a large number of available colors.
- Each framebuffer element is now an index into the color table, where the actual values of each channel are stored.
  - Color table entries can be changed in software.

Color tables on 24-bit systems

Even full-color systems often use color tables. In this case, there is a separate color table for each 8 bit channel.

- Most SGI workstations are like this.
- **Q**: Why would you want this capability?

Double-buffering

- **Q**: What happens when you write to the framebuffer while it is being displayed on the monitor?
- **Double-buffering** provides a solution.

Summary

- Here’s what you should take home from this lecture:
  - The basic components of black-and-white and color CRTs
  - Computing screen resolution & framebuffer size
  - How different display technologies work
  - The correspondence between elements of framebuffer memory and pixels on-screen
  - How color tables work
  - How double-buffering works