Displays and Framebuffers

Steven Tanimoto

Adapted from materials by Brian Curless and Daniel Leventhal

**CSE 457**
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Reading

Required

- Angel, section 1.2, chapter 2
- Hearn & Baker, online handout

Optional

- OpenGL Programming Guide (the "red book" – available online):
  - First four sections of chapter 2
  - First section of chapter 6
- Foley et al., sections 1.5, 4.2-4.5
- I.E. Sutherland. Sketchpad: a man-machine graphics communication system. *Proceedings of the Spring Join Computer Conference,* p. 329-346, 1963.
- T.H. Myer & I.E. Sutherland. On the design of display processors. *Communications of the ACM* 11(6): 410-414, 1968.

Modern graphics systems
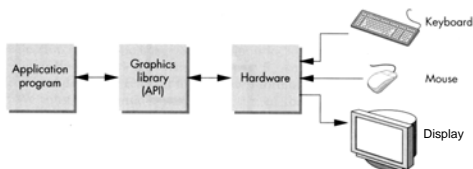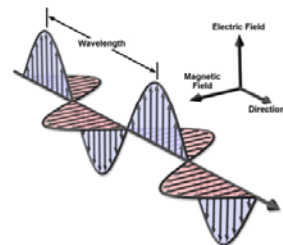

Current graphics systems consist of:

- An application, which talks to a…

- Graphics library (e.g., OpenGL or Direct3D), which talks to the…

- Graphics hardware

The graphics hardware can do a lot of fancy work these days. We'll take a brief tour, starting from the display…

Light as an EM wave

We can model light as an electromagnetic wave:

The E and M fields are tightly coupled, so we usually just talk about the E field.

The orientation of the E field is the polarization. The example above is monochromatic (one wavelength) and linearly polarized (E field oscillates in a line, up and down in this case).

[figure credit:
http://www.magnet.fsu.edu/education/tutorials/tools/faradaycage.html]

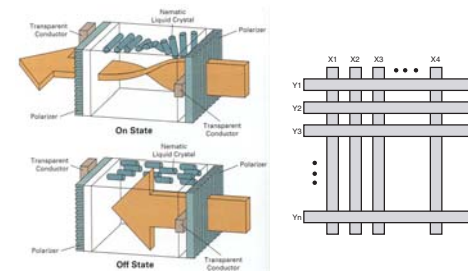## Light as an EM wave (cont'd)

Polychromatic, linearly polarized:

Polychromatic, unpolarized:

A linear polarizer is a filter that extracts the vector component of the light wave along a particular direction.

5

Liquid Crystal Display

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**

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

Active matrix displays have a transistor at each cell. They use a faster switching crystal and transistors that hold charge and prevent overflow.
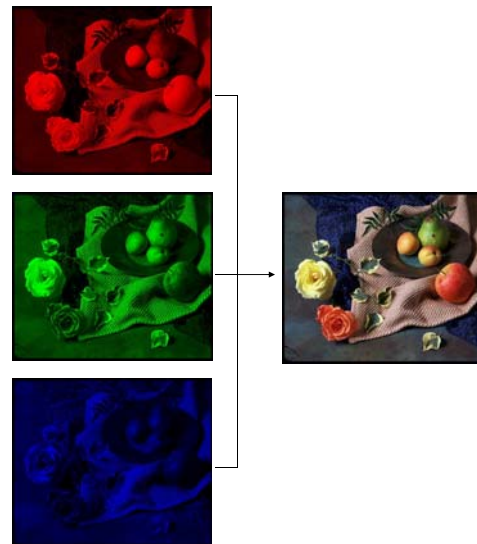
6

Additive color mixing

All colors on a display are produced using combinations of red, green, and blue.
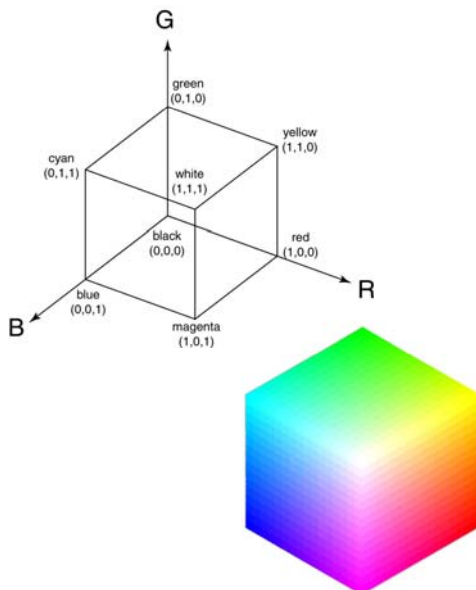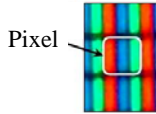

7

Anatomy of an RGB image

8

2

LCD Color

Color is obtained using color filters:

Pixel ←

Pixel is one region on the display corresponding to one color sample of an image being shown.

Our eyes average the closely spaced RGB colors spatially to create the impression of a composite color at each pixel.
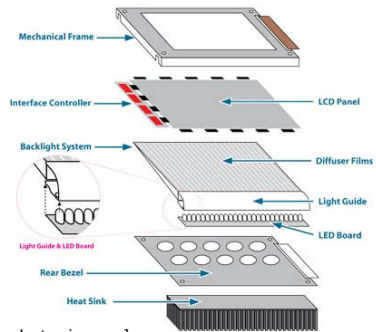
LCD Backlights

Backlighting can be fluorescent or LED:

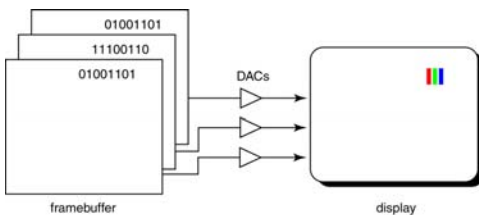The lighting is arranged into a column or a sparse array and then diffused evenly:

RGB framebuffer

The brightness of each LCD element is controlled by a dedicated memory array called a **framebuffer**.

Each element of the framebuffer is associated with a single **pixel** on the screen.

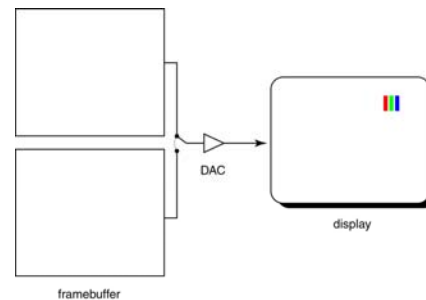Typically, a display allows 256 voltage settings for each of R, G, and B.

We sometimes call each R, G, or B component a **channel** (so the "red channel" of an image is only the R component per pixel.).

Double-buffering

Q: What happens when you write to the framebuffer while it is being displayed on the monitor?

Double-buffering provides a solution.

OpenGL

The API we'll be using for drawing to the framebuffer is OpenGL.

For 2D graphics, OpenGL lets you specify colors of primitives and then draw them to the screen. Typical primitives include:

- Points
- Lines
- Unfilled polygons
- Filled polygons

You just name a color, declare the primitive type, and specify the vertices, and OpenGL does the rest.

OpenGL also supports "alpha" blending. A typical operation is a linear mixture that blends a new color into the framebuffer:

$$F_{new} = \alpha C + (1-\alpha)F_{old}$$

13

Summary

Here's what you should take home from this lecture:

- All of the **boldfaced terms**.
- The principles of operation for an LCD display.
- The correspondence between elements of framebuffer memory and pixels on-screen.
- How double-buffering works.

14