CS 4451A: Computer Graphics

- CCB 101, TT 9:30-11

Why Computer Graphics?

- Fun!
- Lots of uses:
  - Art, entertainment
  - “Visualizing” complex data/ideas
  - Concise representation of actions/commands/state
  - Design/task aids (visual feedback)
Instructor

- Blair MacIntyre
- HCI, Graphics, Systems
- Augmented Reality, Wearable Computers, Ubiquitous Computing

TAs

- Enylton Coelho
- Ben Carter
Basic Course Info

- Quarter equiv: CS 4390 and CS 4391
  - Need both. Only CS 4390? Stay here!
  - Anybody even remember quarters?
- PreReqs
  - MATH 2601 and CS 2330

More Info

- See the web
  - http://www.cc.gatech.edu/classes/AY2003/cs4451a_fall/
- Book (Watt, OpenGL PG) (FvDFH)
- Exams: 2 tests (30%), 1 final (20%)
- Assignments: 5 (50%)
  - Java/OpenGL on Sun/SGI/NT/Mac, lab or home
  - (section B will be using C)
- Syllabus: subject to change
Lectures

- Sometimes will be pre-prepared notes
  - Available on web page before lectures
    - print them and annotate during class!
- Required reading on syllabus
- eClass recording ... alas no.

Introduction

-Raster Graphics Hardware
Basic Definitions

- **Raster**: A rectangular array of points or dots.
- **Pixel (Pel)**: One dot or picture element of the raster.
- **Scan Line**: A row of pixels.

![Raster System Architecture Diagram]

Example Raster Graphics Architecture

Raster system architecture with a display processor.
(from Computer Graphics: Principles and Practice.)
**CRT Monitor**

- Electron Guns
- Red Input
- Green Input
- Blue Input
- Deflection Yoke
- Shadow Mask
- Red, Blue, and Green Phosphor Dots

**Electron Gun**

- Stream of electrons directed to front
  - Num electrons controls brightness

- Phosphor, glows briefly

- Gaussian distribution of electrons, light
**Color CRT**

- RGB electron guns
- Screen coated with phosphor pattern
- Fluorescence
- Phosphorescence
- Persistence

**Shadow Mask**

- Phosphors arranged in triads
- Each triad has one R/G/B phosphor dot
- Typically 2.3 to 2.5 triads per pixel
- Shadow mask has one small hole for each phosphor triad
Aperture Grill

- i.e. Sony Trinitron
- Phosphors arranged in vertical stripes
- Shadow mask is a vertical “grill”

Scanning An Image

- Frame: image to be scanned on CRT
- Frame must be “refreshed” to eliminate flicker in the image.
- Critical Fusion Frequency
  - Typically 60 times/sec for raster displays
  - Varies with intensity, individuals, phosphor persistence, lighting, ...
Interlaced Scanning

- Assume can only scan 30 times/sec
- To reduce flicker, divide frame into two “fields” (odd and even lines)

<table>
<thead>
<tr>
<th>1/30 SEC</th>
<th>1/30 SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/60 SEC</td>
<td>1/60 SEC</td>
</tr>
<tr>
<td>FIELD 1</td>
<td>FIELD 2</td>
</tr>
<tr>
<td>FRAME</td>
<td>FRAME</td>
</tr>
</tbody>
</table>

Scanning

- VERTICAL SYNC PULSE — Signals the start of the next field.
- VERTICAL RETRACE — Time needed to get from the bottom of the current field to the top of the next field.
- HORIZONTAL SYNC PULSE — Signals the start of the new scan line.
- HORIZONTAL RETRACE — Time needed to get from the end of the current scan line to the start of the next scan line.
Resolution and Addressability

Resolution is a measure of the width of a single line drawn on the CRT screen (1/spotsize). Usually stated as the number of just merged lines per inch or centimeter.

Addressability is a measure of the spacing between the centers of those lines.

(Everybody, incorrectly, uses resolution when they mean addressability.)

Resolution < Addressability
Smoothes out the "jaggies" but the overlap will cause filled areas to be brighter than lines, and lines to be brighter than single pixels.

Frame Buffers

- 2D array
  - each (x,y) location = a pixel
- Bit Planes, Bit Depth
  - number of bits in a pixel
- Typical frame buffers:
  - 640 x 480 x 8
  - 1280 x 1024 x 8
  - 1280 x 1024 x 24
1-Bit = Monochrome Display
(Bit-map Display)

3-Bit Color Display

COLOR: black red green blue yellow cyan magenta white

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>G</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
| B | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1
True Color Display
24 bitplanes, 8 bits R/G/B

\[2^{24} = 16,777,216\]

Color Map Look-Up Tables

LUT Video look-up table organization. A pixel with value 67 (binary 01000011) is displayed on the screen with the red electron gun at 9/15 of maximum, green at 10/15, and blue at 1/15. This look-up table is shown with 12 bits per entry. Up to 24 bits per entry are common.
Pseudo Color: $2^8 \times 24$ Color Map LUT

256 colors chosen from a palette of 16,777,216.

Each entry in the color map LUT can be user defined.

Display Processor

- Specialized hardware
  - i.e. scan converts primitives into frame buffer
- Fundamental difference between graphics systems
  - work done by display processor vs. CPU
**Video Controller**

- Cycles through frame buffer
  - FB contents used the control the electron beam intensity (color)

---

**Input Hardware: Logical Devices**

- Locator
  - position and/or orientation
- Keyboard
  - characters and strings
- Valuator
  - single values in the space of real numbers
- Choice
  - select from a set of actions or choices
# Physical Device Examples

- **Locator Devices**
  - Tablet, mouse, trackball, touch panel, Light pen
- **Keyboard devices**
  - Alphanumeric keyboard (coded or unencoded)
- **Valuator Devices**
  - Rotary dials (bounded or unbounded), sliders
- **Choice Devices**
  - Function keys