Adding some light to computing ….

Bits of Color

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Recall that the screen (and other video displays) use red-green-blue lights, arranged in an array of picture elements, or *pixels*.
Actual Pixels From TFT LCD Display
Combining Colored Light

- The Amazing Properties of Colored Light!

- Caution: It doesn’t work like pigment
Green + Red = Yellow?

- Colored light seems to violate our grade school rule of green = blue + yellow. What gives?
- In pigment, the color we see is the reflected color from white light; the other colors are absorbed.
Each Bit Adds Another 1/2

1000 0000
1100 0000
1110 0000
1111 0000
1111 1000
1111 1100
1111 1110
1111 1111
Not All Information Is Discrete

- Analogue information directly applies physical phenomena, e.g. vinyl records
Analog Signals Become Discrete

Sampling the wave ...

Rate 1

Rate 2

Sound pressure

Time
Precision of the Sample

...
The World Is Analog – Go Between

Analog is needed for the “real world”
Digital is best for “information world”
- Can be modified, enhanced, remixed, etc
- Shared, stored permanently, reproduced, ...

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Sampling Sound ...

- Going too slowly misses waves
- Going too fast keeps lots of redundant info
- The range of human hearing is 20-20,000 hz
  - Faster or slower, only the dog can hear it
  - Nyquist Rule: Sampling rate must be twice as fast as fastest frequency to be captured
- For technical reasons, the number is 44,100 hz
- How precise to sample: 16 bits gives -32k to 32k
Multimedia

Many different forms of online information with special representations

- JPG, MP3, MPEG, WAV ...

Most forms of multimedia require many, many bits

- A minute of digital audio:
  - 60 seconds x
  - 44,100 samples per second x
  - 16 bits each
  - x 2 for stereo

- Is 84,672,000 bits, or 10,584,000 B

- 1 hour is 635 MB!
Often, most of the bits are not needed – MP3 audio is less than 1MB/min because many sounds can be eliminated – we can’t hear them.

Compression ... comes in two forms:

- Lossless – eliminated bits can be recovered
- Lossy – eliminated bits are gone for good ... MP3

Susanne Vega sings *Tom’s Diner*
https://www.youtube.com/watch?v=VGw3W10QxLA
Lossless compression seems strange – it eliminates bits that can be recovered again ... weren’t they necessary in the first place???

Consider a fax –

- Usually faxes use a scanner that produces rows of 0s and 1s.
- Compress by counting ... it’s run-length encoding:
  
  0000000000000000000000111111100000000011

  == 22:0,7:1,8:0,2:1
GIF Uses Same Idea

- Graphics Interchange Format (GIF) uses several kinds of compression
  - Color Table
  - Run Length Encoding
  - Lemple/Ziv/Welch Encoding

<table>
<thead>
<tr>
<th>Color Table</th>
<th>Value</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FF 00 00</td>
<td>Red</td>
</tr>
<tr>
<td>2</td>
<td>FF FF FF</td>
<td>White</td>
</tr>
<tr>
<td>3</td>
<td>00 FF 00</td>
<td>Green</td>
</tr>
</tbody>
</table>

Hungary

Italy
Compare Images Using GIF

- Compare Hungarian Flag and Italian Flag
  - huFlag: [15 x 9] 45:1, 45:2, 45:3
  - itFlag: [15 x 9]
    5:3, 5:2, 5:1, 5:3, 5:2, 5:1, 5:3, 5:2, 5:1,
    5:3, 5:2, 5:1, 5:3, 5:2, 5:1, 5:3, 5:2, 5:1,
    5:3, 5:2, 5:1, 5:3, 5:2, 5:1, 5:3, 5:2, 5:1

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Hungary

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JPG is Lossy

- Areas of similar color are represented by one shade ... it’s OK for a while
Facts about physical representation:

- Information is represented by the presence or absence of a physical phenomenon (PandA)
  - Hole punched in a card; no hole [Hollerith]
  - Dog barks in the night; no barking in the night [Holmes]
  - Wire is electrically charged; wire is neutral
  - ETC

Abstract all these cases with 0 and 1; it unifies them so we don’t have to consider the details
Bits Work For Arithmetic

- Binary is sufficient for number representation (place/value) and arithmetic
  - The number base is 2, instead of 10
  - Binary addition is just like addition in any other base except it has fewer cases ... better for circuits
  - All arithmetic and standard calculations have binary equivalents
  - Pixels represented by amount of light intensity
- We conclude: bits “work” for quantities
Bytes illustrate that bits can be grouped in sequence to generate unique patterns:

- 2 bits in sequence, $2^2 = 4$ patterns: 00, 01, 10, 11
- 4 bits in sequence, $2^4 = 8$ patterns: 0000, 0001, ..., 1111
- 8 bits in sequence, $2^8 = 256$ patterns: 0000 0000, ...

ASCII groups 8 bits in sequence:

They seem to be assigned intelligently, but they’re just patterns.
Representing Anything

- Compare binary arithmetic to ASCII
  - Binary encodes the positions to make using the information (numbers) easy, like for addition
  - ASCII assigns some pattern to each letter
- Given any finite set of things – colors, computer addresses, English words, etc.
  - We might figure out a smart way to represent them as bits – colors can give light intensity of RGB
  - We can just assign patterns, and manipulate them by pattern matching – red can be 0000 0001, dark red 0000 0010, etc.
What does this represent:
0000 0000 1111 0001 0000 1000 0010 0000?
You don’t know until you know how it was encoded

- As a binary number: 15,796,256
- As a color, RGB(241,8,32)
- As a computer instruction: Add 1, 7, 17
- As ASCII: \( n_u b_s \) ñ <space>
- IP Address: 0.241.8.32
- Hexadecimal number: 00 F1 08 20
- ... → to infinity and beyond
A Bias-free Universal Medium

- This is the principle:

  **Bias-free Universal Medium Principle:**
  Bits can represent all discrete information; bits have no inherent meaning

- Bits are it!!!
- “Computers encode information with bits, not numbers ... the bits might be numbers, but they might be a lot of other stuff instead”
Assignment 11 – Two Parts

- Goal

- Part 1: HW 11, due Tuesday
- Part 2: Lab 7, do it in lab

Just Do It!