CS 115: COMPUTING FOR THE SOCIO-TECHNO WEB

REPRESENTATION OF DATA:
COLOR, IMAGES, SOUND, AND VIDEO
QUESTION

How do you feel about binary/decimal conversions?

A) Easy peasy
B) I mostly get it but need more practice
C) Sooo hard
D) What’s binary?
TODAY

Decimal, Binary, Hexadecimal numbers (review)
Text representation (review)
Color representation
Image representation
Sound representation
Video representation
NUMBERING SYSTEM REVIEW

$0111_2 =$
A) $9_{10}$
B) $5_{10}$
C) $7_{10}$
D) I don’t know
NUMBERING SYSTEM REVIEW

$3A_{16} =$
A) $310_{10}$
B) $58_{10}$
C) $48_{10}$
D) I don’t know
NUMBERING SYSTEM REVIEW

Positional notation systems:

Base 10 (10 symbols - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9)
• $1492_{10} = 1*1000 + 4*100 + 9*10 + 2*1$
• $2009_{10} = 2*1000 + 0*100 + 0*10 + 9*1$

Base 2 (2 symbols - 0, 1):
• $1010_2 = 1*8 + 0*4 + 1*2 + 0*1 = 10_{10}$
• $0111_2 = 0*8 + 1*4 + 1*2 + 1*1 = 7_{10}$

Base 16 (16 symbols - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F):
• $3A_{16} = 3*16 + A*1 = 58_{10}$
• $B2_{16} = B*16 + 2*1 = 178_{10}$
Converting decimal to hexadecimal:
(1) Left digit: divide by 16, convert quotient to 0..9,A..F
(2) Right digit: convert remainder to 0..9,A..F

Example: \(201_{10} \rightarrow C9_{16}\)
(1) \(201/16 = 12_{10} \rightarrow C_{16}\)
(2) remainder is \(9_{10} \rightarrow 9_{16}\)

Converting hexadecimal to decimal:
(1) Convert left digit to 0..15, multiply by 16
(2) Convert right digit to 0..15, add to (1)

Example: \(A7_{16} \rightarrow 167_{10}\)
(1) \(A_{16}\) is \(10_{10}\), \(10*16 = 160\)
(2) \(7_{16} = 7_{10} \rightarrow 160+7 = 167\)
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HOW MANY UNICODE CHARACTERS?

32 BITS EACH, SO THERE ARE IN ALL

\[ 2^{32} = 4,294,967,296 \]
Computers leverage our senses: vision, auditory
This is essential for human-computer interaction.

The input to these senses can be encoded in bits!

Our senses have limitations:
• Vision: ~ 10 million colors
• Auditory: 20Hz to 20KHz
The human retina has three kinds of color-sensitive photoreceptors that were traditionally called red, green and blue cones.

Visible colors can be created by adding different amounts of the three primary colors, red, green and blue.

Color monitors display colors by adding different amounts of red, green and blue light.

RGB color components are usually defined on a scale from 0 to 255.

Cornflower = 100 149 237
Forest Green = 34 139 34
Gold = 255 215 0
DodgerBlue = 30 144 255
Sienna = 160 82 45
HotPink = 255 105 180
RGB color components are usually defined on a scale from 0 to 255.

How many colors can be represented this way?
A) 256
B) 768
C) 16,777,216
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How many bits do we need for 1 color?

A) 8
B) 24
C) 255
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COLOR

EXPLORE RGB COLOR

1) What shades are created when all three primary colors are equal?

2) How can you make a color brighter or darker?
IMAGES
Images are a 2-dimensional (2D) array of pixels.
Number of pixels = height x width (= resolution)

38 pixels high x 44 pixels wide
IMAGE REPRESENTATION

Size of the image = resolution * data for each pixel

If there are only 2 colors (say black and white), then how many bits per pixel?
  • 1 bit (with 1 = black; 0 = white)

Size of the image: \( w \times h \times 1 \text{ bits} = (w \times h)/8 \text{ Bytes} \)

A 640 x 480 BW image takes:
A) 38,400 Bytes
B) 307,200 bits
C) 37.5 KB
D) All the above
IMAGE REPRESENTATION

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D) All the above
IMAGE REPRESENTATION

Size of the image = resolution * data for each pixel

In a true-color image, how many bits for each pixel?
  • 24 bits because r (8 bits), g (8 bits), b (8 bits)

Size of the image: \( w \times h \times 24 \text{ bits} = \frac{(w \times h \times 24)}{8} \text{ Bytes} \)
A 640 x 480 color image takes
921,600 B = 900 KB!
**BIT DEPTH**

Bit depth is the number of bits required to represent the color for individual pixel.

How many colors with bit depth of 4?

How many colors with bit depth of 24?
IMAGE COMPRESSION (GIF)

HONESTLY, I THINK I MAY HAVE CLEANED IT A LITTLE TOO WELL.
How large is a file that stores a 300x500 pixel indexed color image with 4 colors, and its color palette?

(1) 300x500 pixels, with 2 bits per pixel (why?)

$$300 \times 500 \times 2 = 300,000 \text{ bits}$$

(2) 4 colors, with 24 bits per color

$$4 \times 24 = 96 \text{ bits}$$

$$\Rightarrow \sim 37.5\text{kB} \text{ (compared to the 450kB uncompressed file!)}$$
Computing the file size for a GIF image, in bytes:

1. Number of bytes to store the image pixels: \( \frac{\text{width} \times \text{height} \times \text{bit-depth}}{8} \)
2. Number of bytes to store the color palette: \( \text{num\_colors} \times 3 \)

3. Total number of bytes:

\[
\frac{\text{width} \times \text{height} \times \text{bit-depth}}{8} + 3 \times \text{num\_colors}
\]

4. Divide by 1,024 or 1,048,576 to convert to kilobytes or megabytes

*There’s also a small amount of fixed overhead for storing file type, dimensions, etc.*
Produced by vibration of object in air, liquid

Moves through waves of pressure
- Is fast: in air, 340 m/sec = 750 miles per hour
- But not very fast (echo)
UNITS

- **Frequency** (aka pitch): Unit: Hz = cycles/sec
  Detectible frequency between 20 Hz and 20KHz, depends on age (mosquito buzz)

- **Amplitude** (aka loudness): Unit: deciBell
A signal can be reconstructed from samples taken at regular intervals as long as the intervals are short enough.
If the samples are too infrequent a lower-frequency signal may fit the sampled points and the original signal can’t be recovered.
DIGITIZING SOUND

Sampling Rate:
Sample the sound amplitude often enough so that you get a close approximation.

Quantization (aka bit depth):
Use a detailed “ruler” so that you get a more accurate reading.

The reproduced signal might not be identical to the original
But might be “good enough”
DIGITIZING SOUND

\[ n \text{ bits/sample} \implies 2^n \text{ possible sample values} \]

Audio CDs, most digital audio uses 16 bits/sample * 2 channels for stereo
FROM ANALOG TO DIGITAL

Sampling Rate

• # of samples/sec
• Usually between 11.0 and 44.1 KHz
• Digital telephones sample at 8.0KHz
• Voice Over IP(e.g., skype) can have higher fidelity than telephone land lines!
• High Quality mono = 44 KHz * 16/8 bytes = 88 Kb/sec!

Bit-resolution (bit depth)

• # of bits devoted to record each sample
• Usually between 8 and 16 bits (1-2 bytes)

Audio file size = sampling rate * bit depth / 8 * recording time * num of channels
Some ideas:

- Throw away very high frequency components
- Throw away any component that is both soft and loud simultaneously
- Change stereo to mono (50% savings)
- These standards stipulate *decoding* but not *encoding* -- there may be several encodings of the same music that discard different information to produce different storage sizes and bit rates
TODAY

Decimal, Binary, Hexadecimal numbers (review)
Text representation (review)
Color representation
Image representation
Sound representation
Video representation
Say you watch 10mins of an uncompressed Netflix video:

The image resolution of Netflix is 1280 wide and 720 high. The number of images per second: 30 frames per second (frame rate).

Calculate the size of the video with no compression:
1. Calculate the size of an individual image in true-color.
2. Calculate the size of the sound for one second of video.
3. Calculate the size of video (sound + images) for one second of video.
4. Calculate the size of the video (sound + images) for one minute of video.
5. Calculate the size of the video (sound + images) for 10mins of video.
Say you watch 10mins of an uncompressed Netflix video:

The image resolution of Netflix is 1280 wide and 720 high.
The number of images per second: 30 frames per second (frame rate).

Calculate the size of the video with no compression:
Calculate the size of an individual image in true-color.
1280 * 720 * 24 = 22,118,400 bits = 2,764,800 Bytes or 2.6MB
Calculate the size of the sound for one second of video.
44*16*2 = 1408 bits per second = 176 KBps
Calculate the size of video (sound + images) for one second of video.
Size per second: 2.6MB*30+176KB = 78MB
Calculate the size of the video (sound + images) for one minute of video.
Size for 1min: 78MB*60 = 4.5GB per min
Calculate the size of the video (sound + images) for 10mins of video.
Size for 10min: 45GB per 10min

If you have 25Mbps, how long will it take to download the video?
360,000,000,000 (bits) / 25,000,000 = 14,400 seconds or 240min or 4hours
DATA THAT TRAVELS THE INTERNET AS 1 AND 0

Amplitude

Crest

Cycle

Valley

Time
TO-DO

Assignment 2 due today
Weekly reflection due tomorrow

Next week: Grace Abuhamad ’13 will join us!
After Wellesley, she worked at ICANN (Internet Corporation for Assigned Names and Numbers) and then at the Department of Commerce working on Internet Governance. Currently, she is a student at MIT in the Technology & Policy Program in the Internet Policy Research Initiative lab. Come with questions!