CS101 Lecture 12: Digital Images

Sampling and Quantizing
Using bits to Represent Colors and Images

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What You’ll Learn Today

- What is digital information?
- How to describe an image
- What is color?
- How do pictures get encoded into binary representation?
- Why do images take so long to download from the web?
A picture is worth…

… a thousand words?

Describe this image with enough detail to recreate it.

How would a computer describe the image?

Analog and Digital Information

We say that information can be represented in one of two ways: **analog** or **digital**.

**Analog**

A *continuous* representation, analogous to the actual information it represents.

**Digital**

A *discrete* representation, breaking the information up into finite elements.
**Analog Information**

Example: Analog Thermometer

The mercury (or alcohol) rises continuously in direct proportion to the temperature.

*What exactly is this reading?*

**Digital Information**

Example: Digital Thermometer

This reading is discrete. Some detail is lost in converting to digital information.

*What is the actual temperature?*
Digital Information

Computers store information in binary numbers. For anything else, we need to digitize the data.

**Digitizing**

Creating a discrete representation of analog data, suitable for storage and manipulation by a digital computer.

- Digitizing involves sampling and quantizing.

Consider this picture.
How to represent it digitally (i.e. in bits)?
Sampling Activity: trace the picture...
For each square you must fill it in completely or else leave it blank.

36 squares

Sampling Activity: trace the picture...
For each square you must fill it in completely or else leave it blank.

144 squares
Digitizing an Image: Sampling

Sampling:
Taking measurements (of color) at discrete locations within the image.

*What sampling rate should we use?*

Photo is 2.5 x 3.5 inches

16 samples per inch (in each direction)
Digitizing an Image: Sampling

**Sampling:**
Measure the color for each pixel, and record that color.

*16 pixels per inch*

**Pixel** is short for picture element - a discrete point of light (color) in a picture.

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Digitizing an Image: Sampling

**Sampling:**
Measure the color for each pixel, and record that color.

*32 pixels per inch*

**Pixel** is short for picture element - a discrete point of light (color) in a picture.
What Your Digital Cameras Does

An image sensor measures the color at each pixel.

- Megapixel ~ 1 million pixels
- One megapixel: 1200 * 900
- 10 megapixels: 3872 * 2592
- iPhone 5 camera: 3264 x 2448 ~ 8 megapixels

Pixelation

Information between pixels is lost. Pixel interpolation attempts to recreate the missing information.
What is color?

Light is a electromagnetic waveform. Color is how we perceive different wave lengths.

- AM radio waves are about 100 meters
- FM radio/TV waves are about 1 meter
- Light waves are about 0.000005 meters

Measuring Colors

Color is how we perceive of the frequencies of light that reach the retinas of our eyes.

The human retina has three types of color photoreceptor cone cells that correspond to the colors of red, green, and blue.
RGB Color Encoding

The RGB color model is an additive model, in which red, green, and blue (RGB) light is combined in various ways to reproduce other colors.

Quantization of colors

Quantization is the process of assigning discrete values to measurements taken in samples.

We need to make choices about:
- Range of values (minimum, maximum)
- Number of steps between min and max
RGB Color Encoding

We quantify each of the red, green, and blue components of a color along a continuum from “totally off” to “totally on”.

0% 100%

Quantization: Color Depth

Color Depth refers to the number of bits used to represent a color.

Color Graphics Adapter
The original CGA color monitor from IBM (~1981).

6 bits total, 2 bits per color supported up to 64 possible colors \((2^6 = 64)\)

(only 16 at a time, though)
Why Color Depth Matters

24-bit color depth is often called TrueColor:
8 bits for red, 8 bits for blue, 8 bits for green
- 24 color bits \( \Rightarrow 2^{24} \) or 16,777,216 colors
# 24-bit Color Depth

We quantify each of the red, green, and blue components of a color along a continuum from “totally off” to “totally on”.

<table>
<thead>
<tr>
<th>00000000 or 0x00</th>
<th>11111111 or 0xFF</th>
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## A Sampling of RGB Color Codes

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Raster/Bitmapped Graphics

Storage of data on a pixel-by-pixel basis
- Common formats include: Bitmap (BMP), GIF, JPEG, and PNG
- BMP images are administratively simple: each pixel is just recorded as its color codes.
- GIF, JPG, and PNG images use compression algorithms

How much data is for a BMP image?
- Typical image size might be 1024 by 768 pixels (= 786,432 pixels)
- 786,432 pixels * 3 bytes per pixel = 2,359,296 bytes (for one picture)
- A 10Mpixel picture would be 30,000,000 bytes.

```
A dog in hexadecimal.
```

```
azs-laptop:images azs$ hexdump -x cody-small.bmp | more  
0000000 4d42 7e78 0005 0000 0000 0036 0000 0028
0000010 0000 012c 0000 0190 0000 0001 0018 0000
0000020 0000 7e42 0005 5890 0000 5890 0000 0000
0000030 0000 0000 0000 0000 0000 0000 0000 0000
0000040 ccbd bda1 a9ca cdc0 c1ab a1cf c9bc b799
0000050 98c4 c1b3 b392 930f c1b5 b59b a3c2 c5b9
0000060 b59b a8c1 c70a c1b1 adcd ccc0 b69a 93c4
0000070 c1b1 b69d adc4 cobe c1b5 bdcf d4c8 ab8a
0000080 c1b1 5481 6e50 468a 826b 9c75 b3b0 d2c2
0000090 c0ad b5cf d1c3 c3b3 b2d2 d2c2
00000a0 d3c4 c2b4 a6d4 cbdb 8b62 8894
00000b0 05cd caba ac85 83ba b19d 8f7e
00000c0 8976 74a3 9f87 8773 839b 9c8a
00000d0 9a84 8575 8096 9c85 8985 869f
00000e0 8c09 9e91 8e81 879b 9d88 8982
00000f0 877d 8098 9887 8e89 8e9d a38e
0000100 a292 8c89 af9d 9b87 817e 8a97
0000110 8a9c 9d87 8687 8195 9481 8484
0000120 827e 7893 907e 847e 8496 9288
```
What You Learned Today

- Analog and Digital Information
- Sampling: Pixels and Resolution
- RGB Color Encoding
- Quantizing: Color Depth
- Factors in image file size
Student To Dos

- **Readings:**
  - Wong ch 1 pp 13-19, ch 2, pp 26-44 (today)
  - Wong ch 3, pp 66-86 (Friday)

Red-Blue combinations
RGB Color Model

Color is expressed as an RGB value – three numbers that indicate the relative contribution of each of these primary colors.

Digitizing an Image: Sampling

Consider this drawing.
Digitizing an Image: Sampling

To sample it, we apply a grid system.

Each cell is a “pixel”.

A pixel is either it’s colored in or not (“on” or “off”).

Digitizing an Image: Sampling

To collect more detail, sample the picture more frequently (more pixels per unit of space).