CS 262 Lecture 01:
Digital Images and Video

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Overview/Questions

- What is digital information?
- What is color?
- How do pictures get encoded into binary representation?
- Why do images take so long to download from the web?
- Understanding the idea of a “motion picture.”
- What is digital video?

Analog and Digital Information

Computers are finite!

How do we represent an infinite world?

We represent enough of the world to satisfy our computational needs and our senses of sight and sound.

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

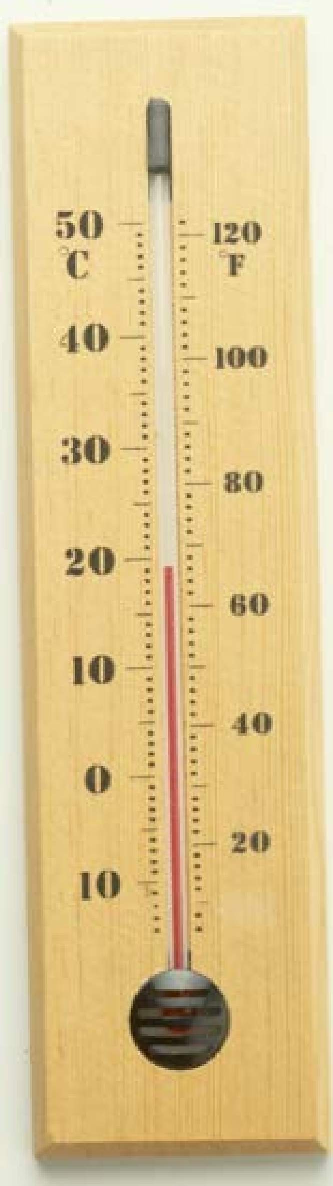
A **discrete** representation, breaking the information up into finite elements.

Analog Information

Example: Analog Thermometer

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

What exactly is this reading?

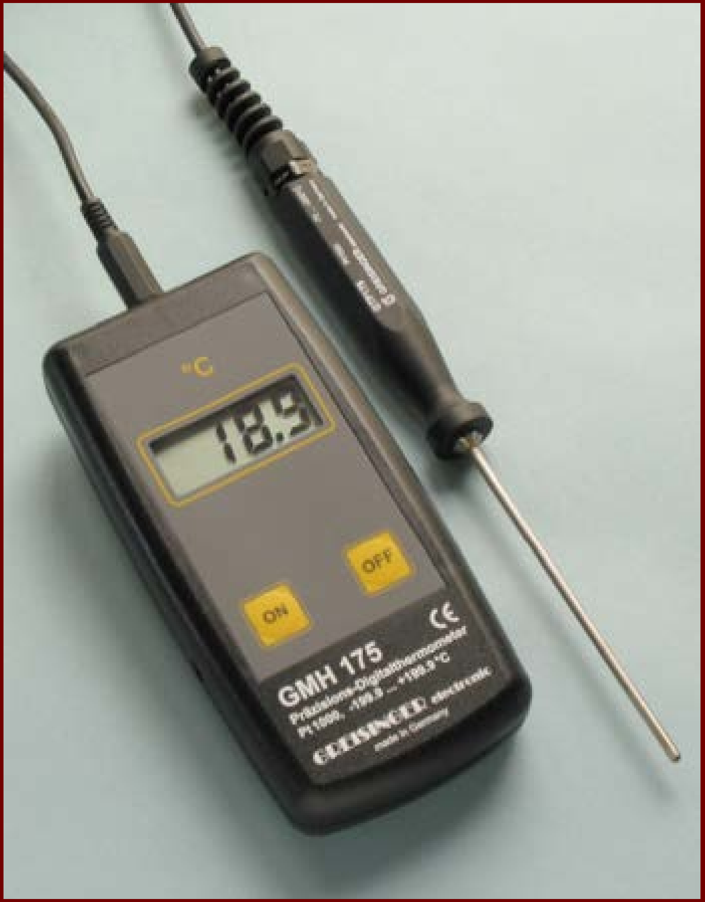


Digital Information

Example: Digital Thermometer

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

What is the actual temperature?



Analog and Digital Information

Computers store information in a discrete form (binary). To represent analog information, we need to digitize the data.

Digitizing

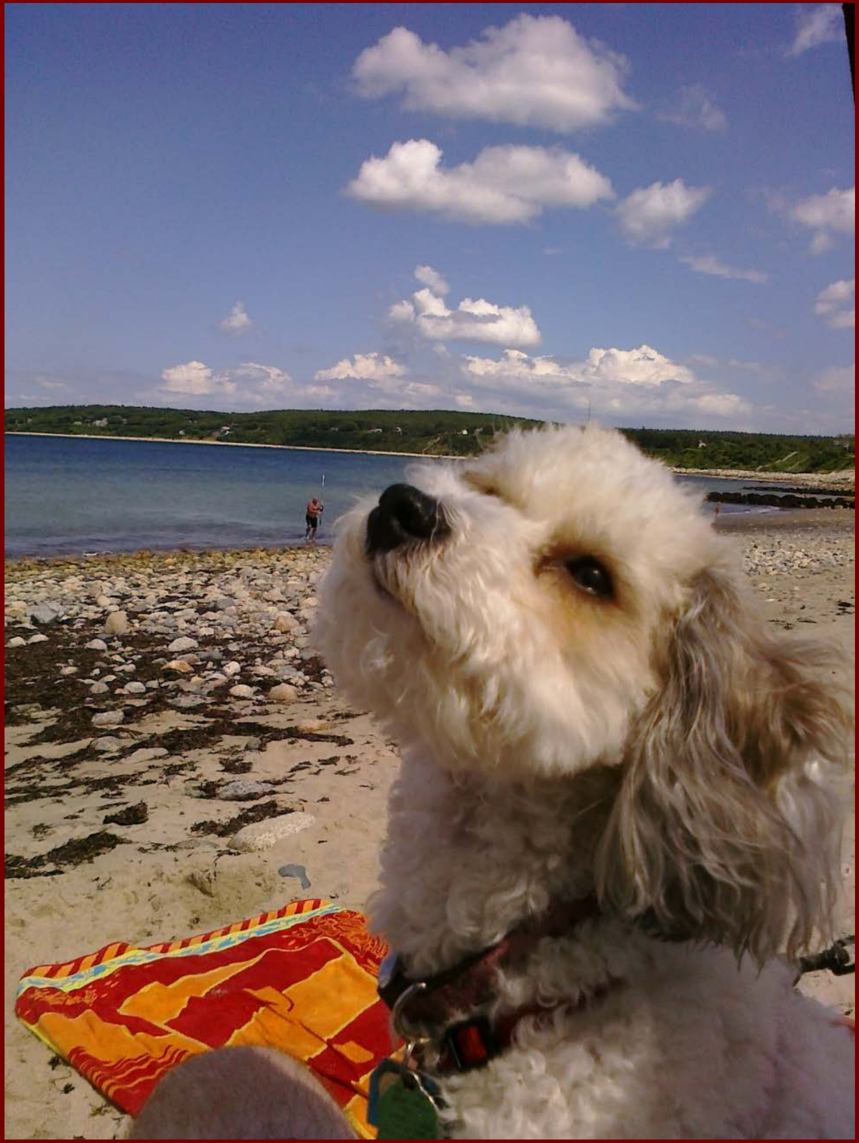
Creating a discrete representation of analog data, suitable for storage and manipulation by a digital computer.

A picture is worth…

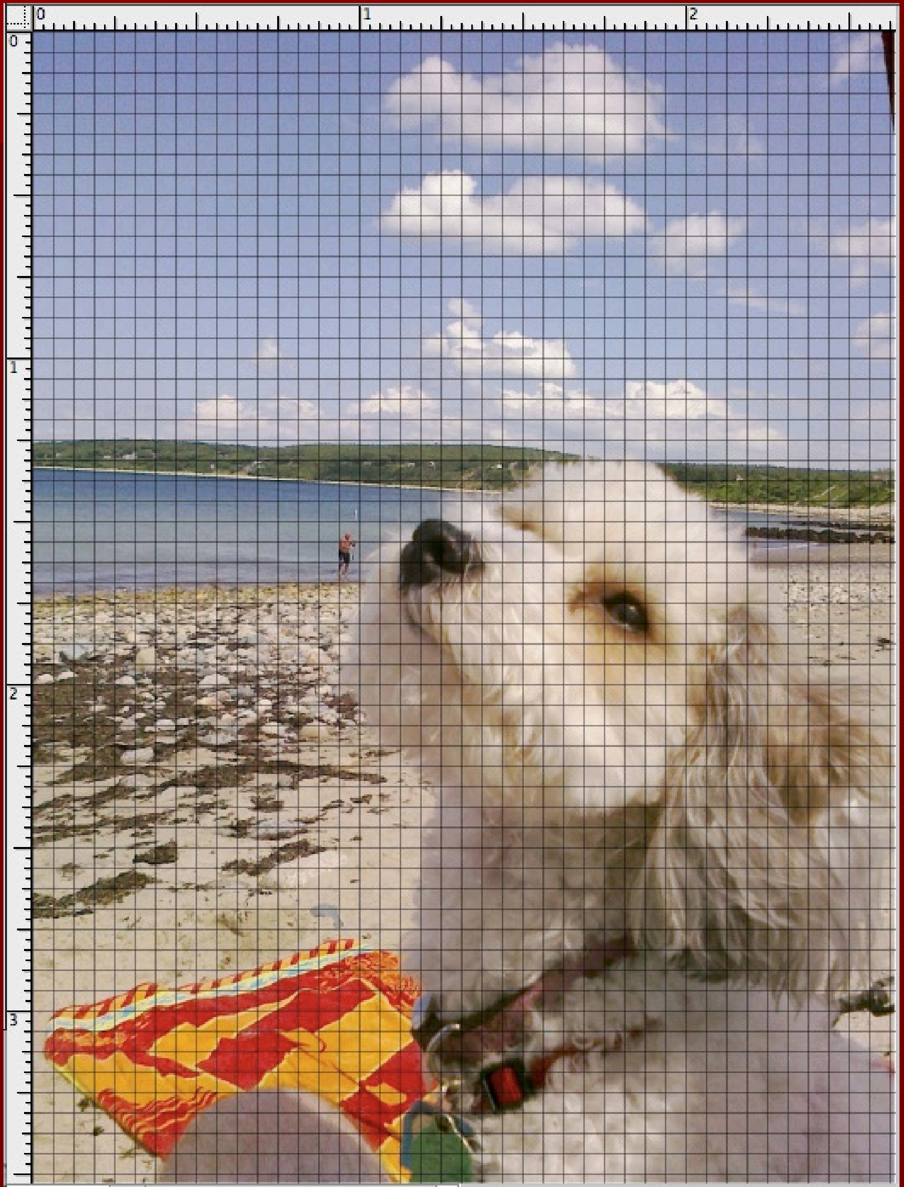
… a thousand words?

Describe this image with enough detail to recreate it.

How would a computer describe the image?



Digitizing an Image



Sampling:

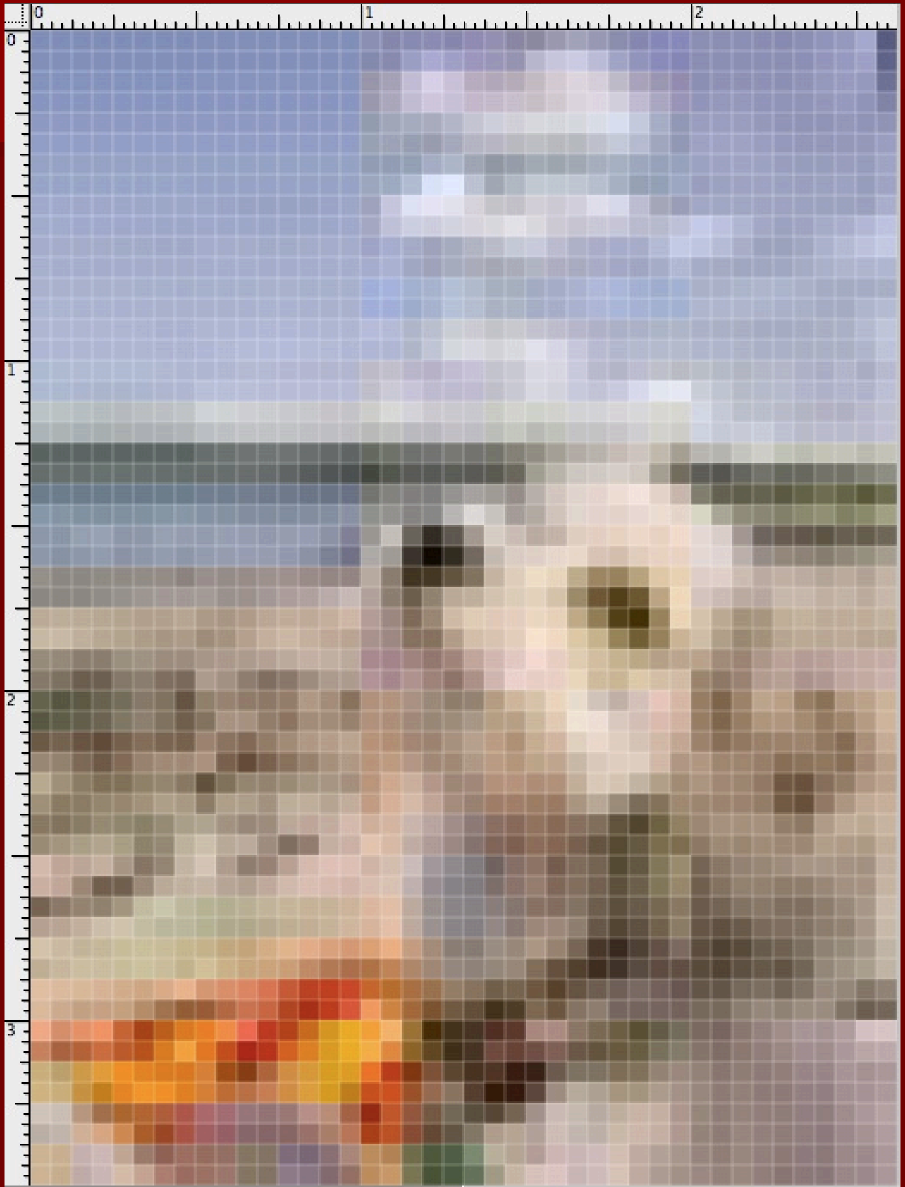
Taking measurements (of color) at discrete locations within the image.

Sampling rate:

16 samples per inch

(in each direction)

Digitizing an Image



Sampling:

Measure the color for each pixel, and record that color.

16 pixels per inch

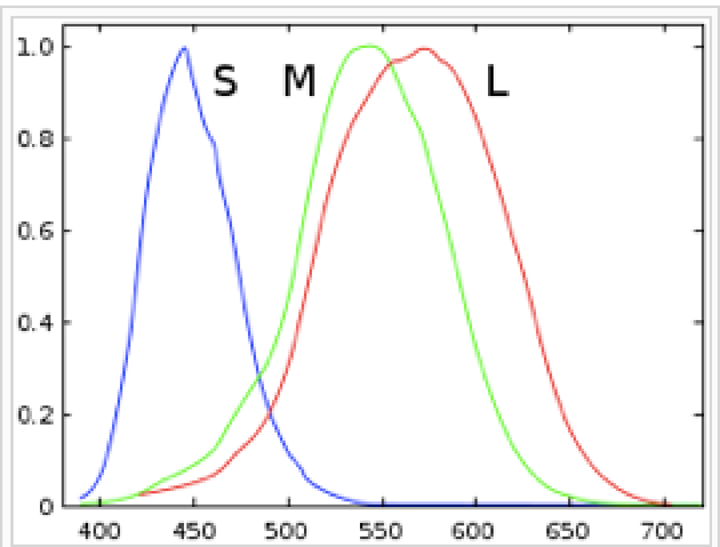
Quantization: determine a discrete value for each pixel.

Representing Images

Color

Our perception 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.

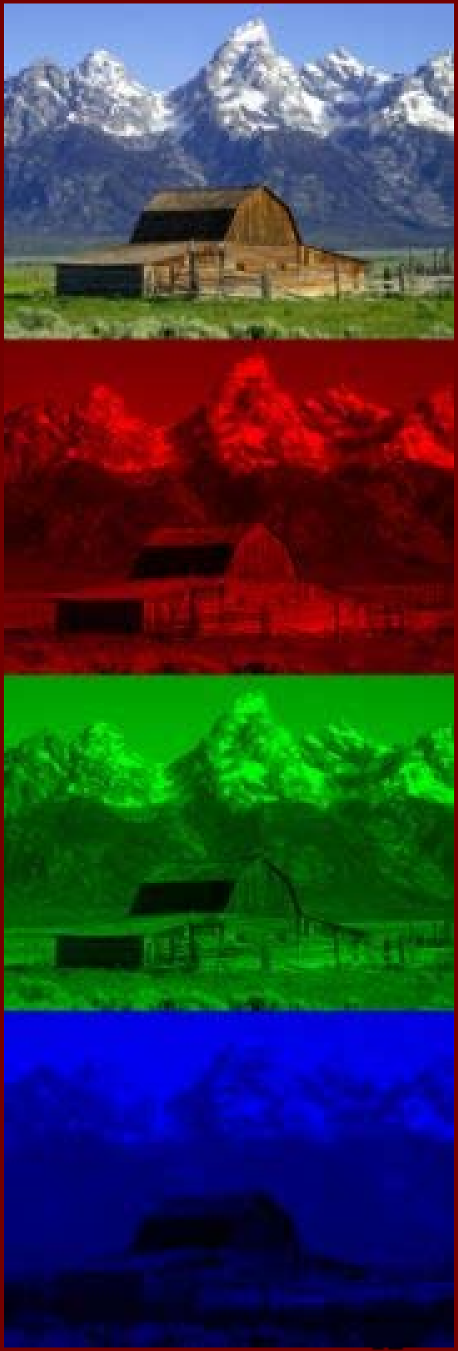


Spectra of visible light (in nm)

RGB Encoding

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

Here is a picture taken in full color, along with its red, green, and blue components.



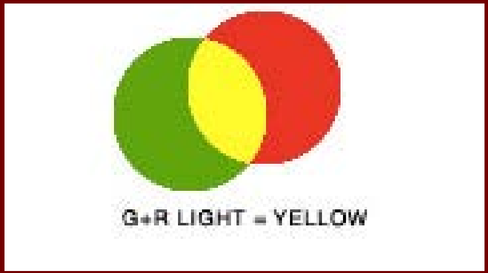
RGB Encoding

Color is expressed as an RGB value –

three numbers that indicate the relative contribution of each of these primary colors.

Color mixing example:

Turn on all red and all green and no blue, which results in a bright yellow.



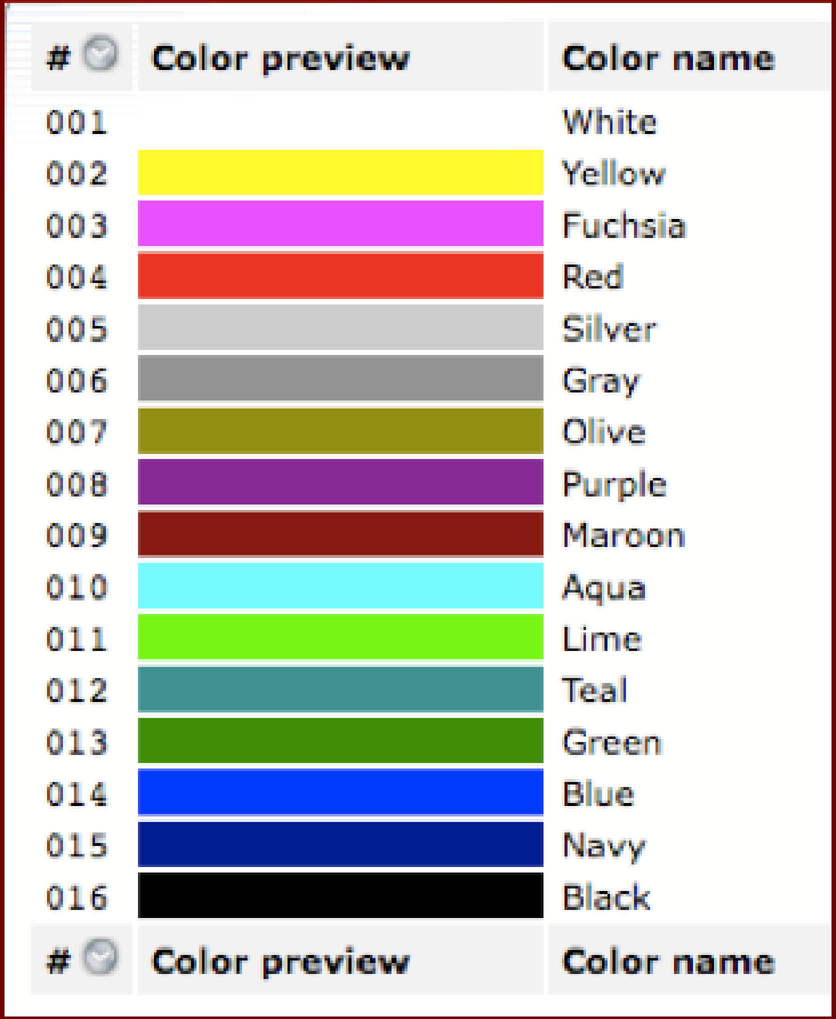
Color Depth

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

Color Graphics Adapter

The original CGA color monitor from IBM.

- 2 bits per color (6 bits total)
- supported up to 64 possible colors ($2^6 = 64$)
- (only 16 at a time, though)



#	Color preview	Color name
001	⬜	White
002	🟨	Yellow
003	🟪	Fuchsia
004	🟥	Red
005	⬜	Silver
006	⬛	Gray
007	🟫	Olive
008	🟪	Purple
009	🟫	Maroon
010	🟦	Aqua
011	🟩	Lime
012	🟦	Teal
013	🟩	Green
014	🟦	Blue
015	🟦	Navy
016	⬛	Black
#	Color preview	Color name

The standard 16 CGI colors

Color Depth

HiColor

A 16-bit color depth: five bits used for each number in an RGB value with the extra bit sometimes used to represent transparency

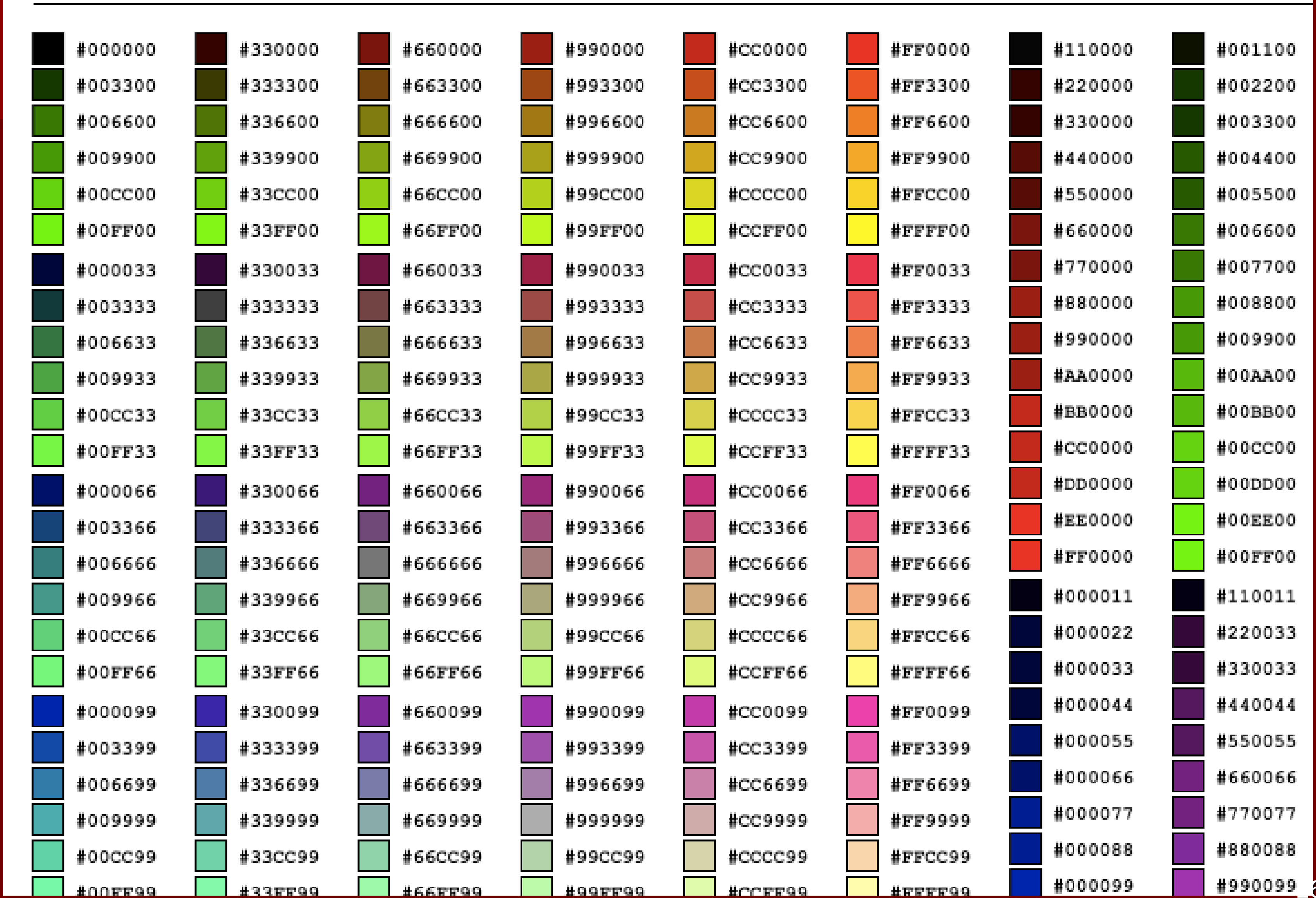
- – 15 color bits ➔ 2^{15} or 32,768 colors

TrueColor

A 24-bit (3 byte) color depth: eight bits used for each number in an RGB value

- – 24 color bits ➔ 2^{24} or 16,777,216 colors

A Sampling of RGB Color Codes



#000000	#330000	#660000	#990000	#CC0000	#FF0000	#110000	#001100
#003300	#333300	#663300	#993300	#CC3300	#FF3300	#220000	#002200
#006600	#336600	#666600	#996600	#CC6600	#FF6600	#330000	#003300
#009900	#339900	#669900	#999900	#CC9900	#FF9900	#440000	#004400
#00CC00	#33CC00	#66CC00	#99CC00	#CCCC00	#FFCC00	#550000	#005500
#00FF00	#33FF00	#66FF00	#99FF00	#CCFF00	#FFFF00	#660000	#006600
#000033	#330033	#660033	#990033	#CC0033	#FF0033	#770000	#007700
#003333	#333333	#663333	#993333	#CC3333	#FF3333	#880000	#008800
#006633	#336633	#666633	#996633	#CC6633	#FF6633	#990000	#009900
#009933	#339933	#669933	#999933	#CC9933	#FF9933	#AA0000	#00AA00
#00CC33	#33CC33	#66CC33	#99CC33	#CCCC33	#FFCC33	#BB0000	#00BB00
#00FF33	#33FF33	#66FF33	#99FF33	#CCFF33	#FFFF33	#CC0000	#00CC00
#000066	#330066	#660066	#990066	#CC0066	#FF0066	#DD0000	#00DD00
#003366	#333366	#663366	#993366	#CC3366	#FF3366	#EE0000	#00EE00
#006666	#336666	#666666	#996666	#CC6666	#FF6666	#FF0000	#00FF00
#009966	#339966	#669966	#999966	#CC9966	#FF9966	#000011	#110011
#00CC66	#33CC66	#66CC66	#99CC66	#CCCC66	#FFCC66	#000022	#220033
#00FF66	#33FF66	#66FF66	#99FF66	#CCFF66	#FFFF66	#000033	#330033
#000099	#330099	#660099	#990099	#CC0099	#FF0099	#000044	#440044
#003399	#333399	#663399	#993399	#CC3399	#FF3399	#000055	#550055
#006699	#336699	#666699	#996699	#CC6699	#FF6699	#000066	#660066
#009999	#339999	#669999	#999999	#CC9999	#FF9999	#000077	#770077
#00CC99	#33CC99	#66CC99	#99CC99	#CCCC99	#FFCC99	#000088	#880088
#00FF99	#33FF99	#66FF99	#99FF99	#CCFF99	#FFFF99	#000099	#990099

Digitized Images and Graphics

Digitizing a picture

Representing it as a collection of individual dots of color called picture elements (pixels).

Resolution

The number of pixels used to represent a picture, measured in width times height.

Standard screen resolution is 1024 x 768.

Spatial Sampling – The sampling happens two “space” dimensions.

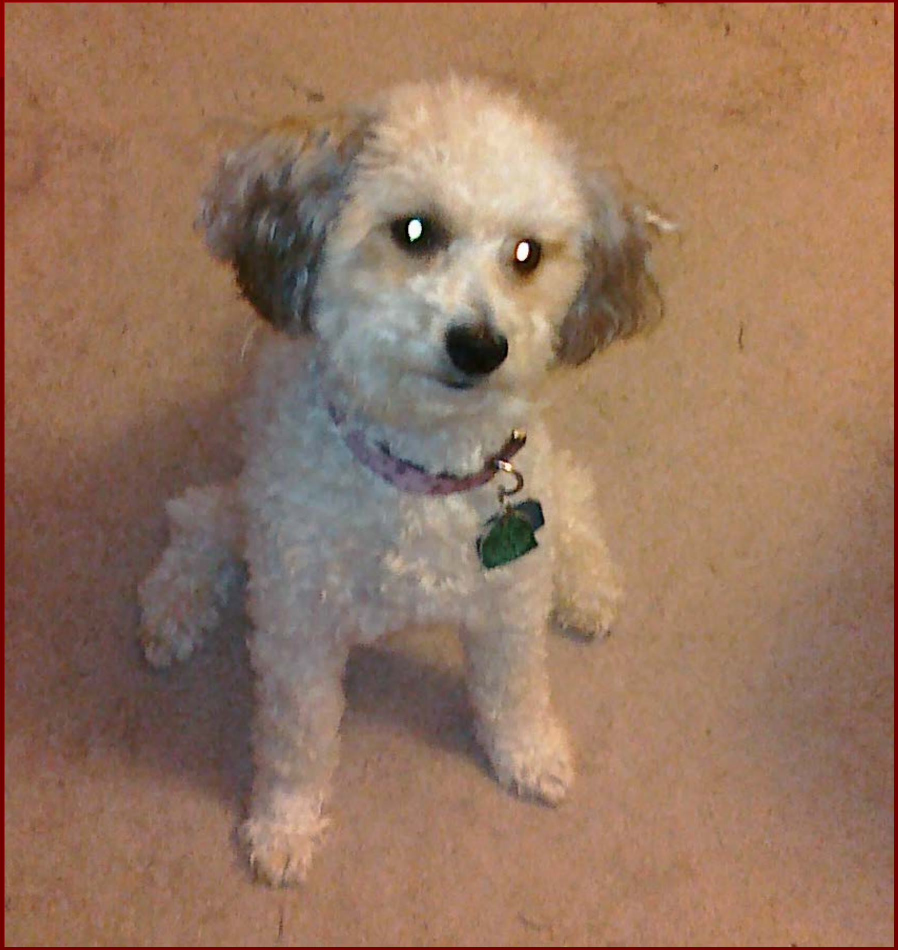
What Digital Cameras Do

A digital camera has electronic image sensor which measures the color at each pixel.

- One megapixel: 1200 * 900
- 10 megapixels: 3872 * 2592

http://www.comedycentral.com/episodes/hn0e41/futurama-the-thief-of-baghead-season-7-ep-704

Digitized Images and Graphics



A digitized picture composed of many individual pixels.

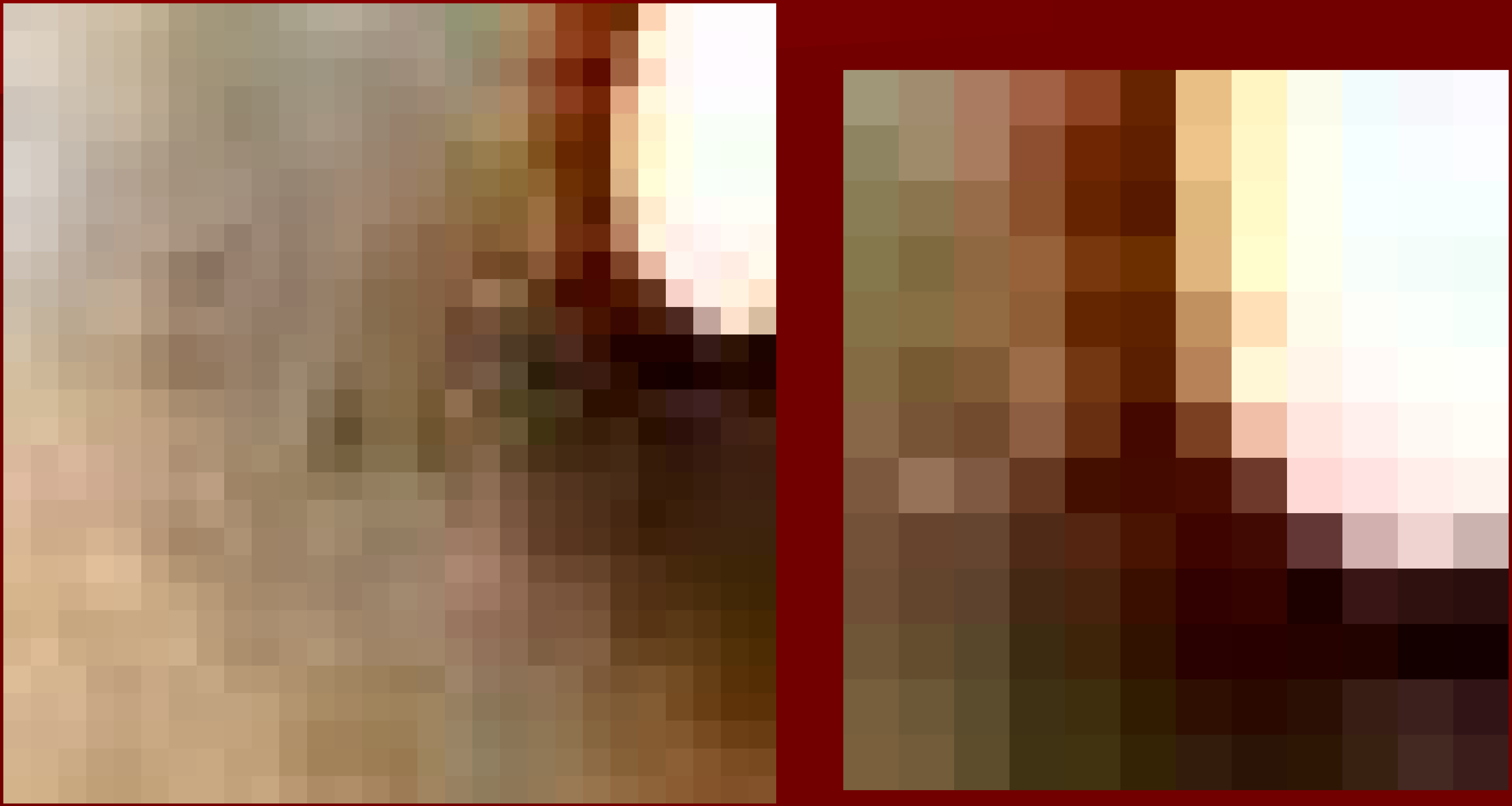
- The color values of the pixels are stored in 2D arrays.
- Eg.

  RGB RGB RGB...

  RGB RGB RGB...

  ...

Digitized Images and Graphics



In this magnified portion, we can see the individual pixels.

Digitized Images and Graphics

Raster/Bitmap Graphics

Storage of data on a pixel-by-pixel basis

- Bitmap (BMP), GIF, JPEG, and PNG, for example

How much data is required to represent a picture?

- Typical size might be 1024 by 768 pixels (~ 800,000)
- At 3 bytes per pixel, about 2,400,000 bytes for one picture!

Same Picture, many formats

Original image was

2048 * 1536 pixels

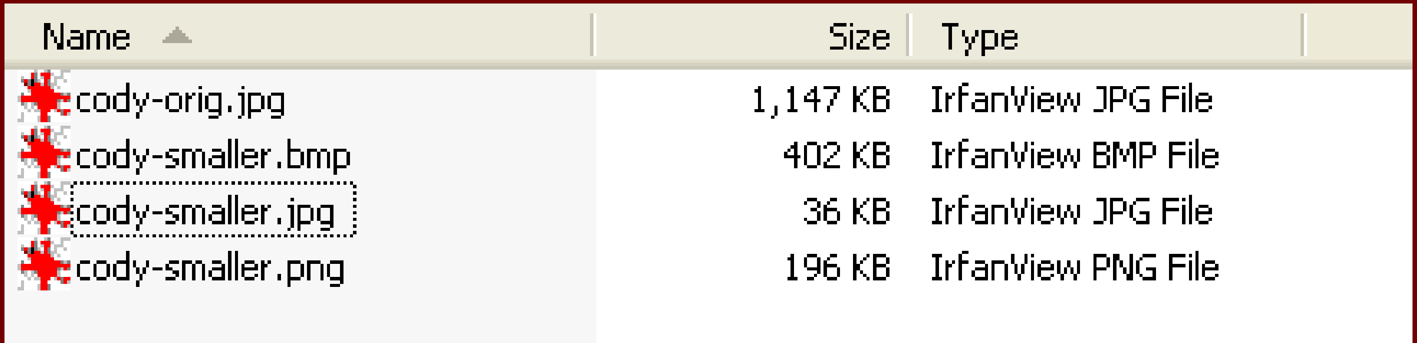
All others are

320 * 428 pixels

Note Bitmap:

320 * 428 * 3

= 410880 bytes



Name	Size	Type
cody-orig.jpg	1,147 KB	IrfanView JPG File
cody-smaller.bmp	402 KB	IrfanView BMP File
cody-smaller.jpg	36 KB	IrfanView JPG File
cody-smaller.png	196 KB	IrfanView PNG File

Data Compression

Data compression

Reduction in the amount of space needed to store a piece of data.

Data compression techniques can be:

- **lossless**, which means the data can be retrieved without any loss of the original information
- **lossy**, which means some information may be lost in the process of compaction

Question: How does data compression affect your ability to write a program that deals with the raw data?

Raster Graphics Formats

Bitmap format

24-bit. Contains the pixel color values for every single pixel in the image. Not compressed.

GIF format (indexed color)

Each image is made up of only 256 colors.

JPEG format

24-bit color, with lossy compression.

JPEG can typically achieve 90% or 95% reduction in file image size without a visible loss in quality.

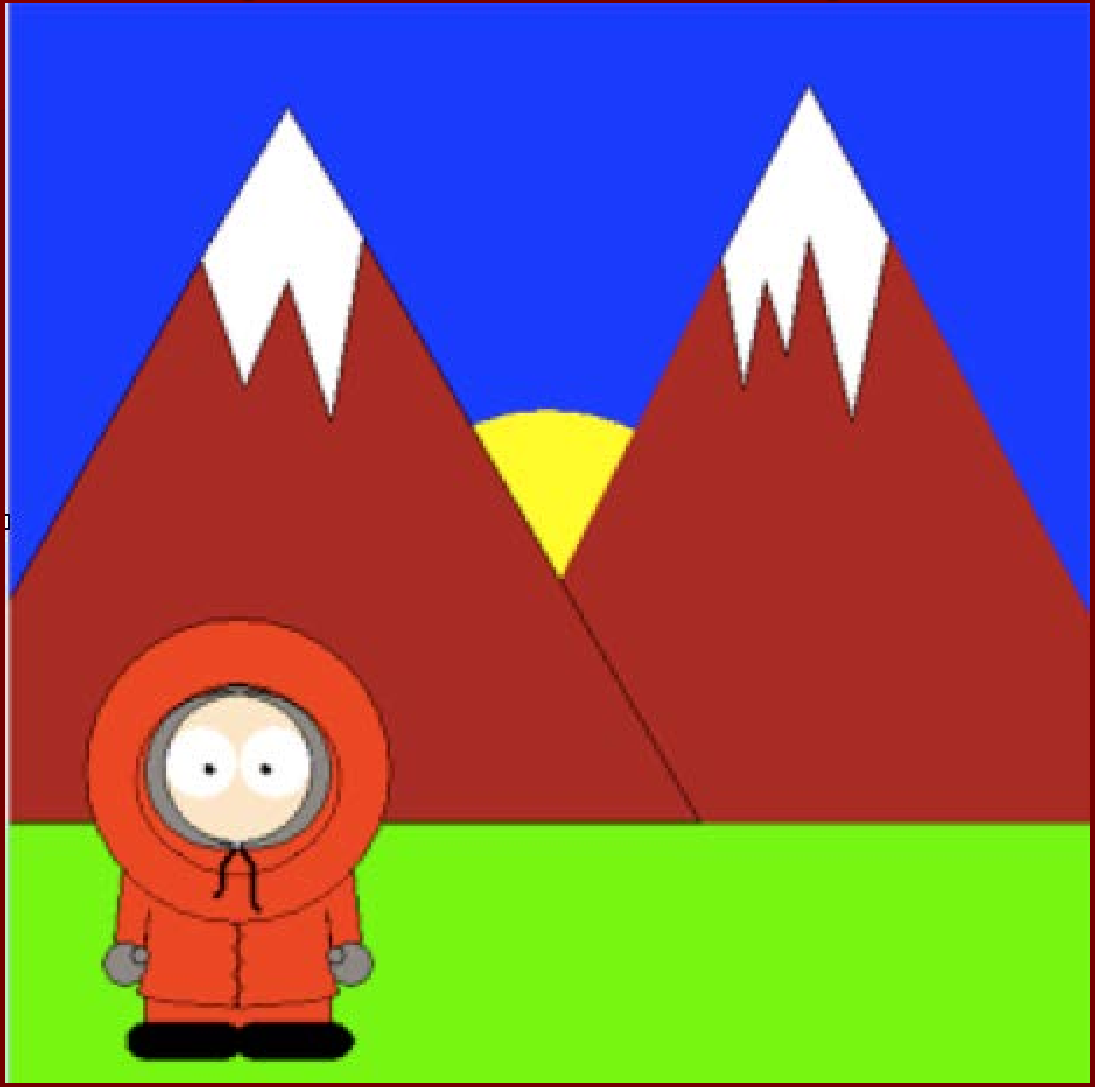
Additional Reference:

http://en.wikipedia.org/wiki/Image_compression

http://www.faqs.org/faqs/jpeg-faq/part1/

Vector Graphics Example

“Describe” this picture…



Vector Graphics assignment by CS108 student, Spring 2008

Vector Graphics

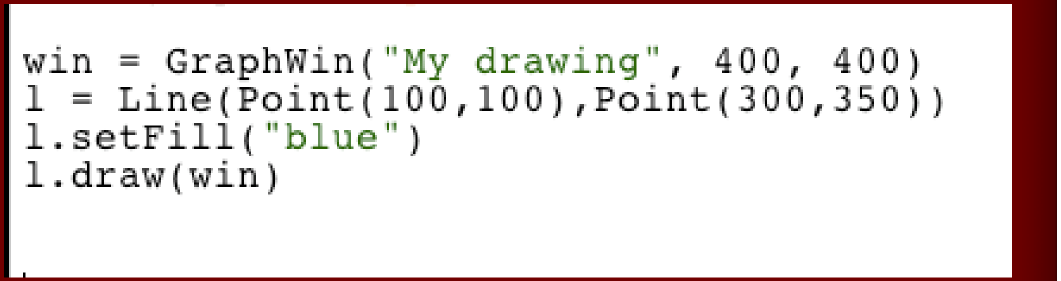
Vector Graphics

A format that describes an image in terms of lines and geometric shapes.

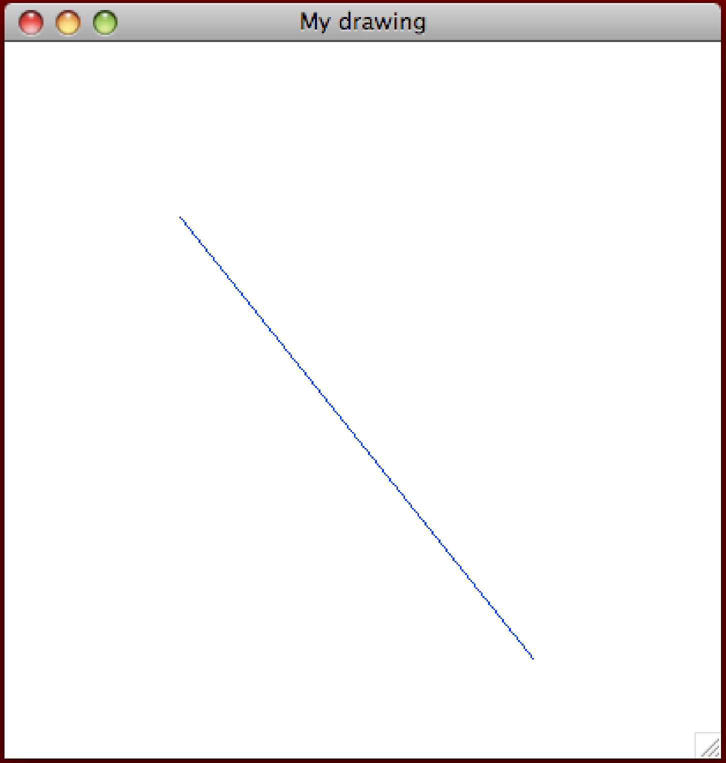
A series of commands that describe a line’s direction, thickness, and color.

Vector Graphics Example

A vector-graphics example in Python.



```
win = GraphWin("My drawing", 400, 400)
l = Line(Point(100,100),Point(300,350))
l.setFill("blue")
l.draw(win)
```



Vector Graphics

Advantages:

- Small file sizes
- Resize mathematically

What are the disadvantages?

Raster vs Vector Graphics

Which format is better for certain pictures?

Drawings, Diagrams, etc.

Lifelike images.

Image Manipulation Software

Recall: We use software to do different things with computers.

There are many different image manipulation software packages, e.g.:

- Paint – Built in to windows
- Photoshop – Commercial software
- Irfanview – Free software
- Paintshop Pro – Shareware/Commercial
- GIMP – Free software

Who invented moving pictures?

"I am experimenting upon an instrument which does for the eye what the phonograph does for the ear, which is the recording and reproduction of things in motion ...."

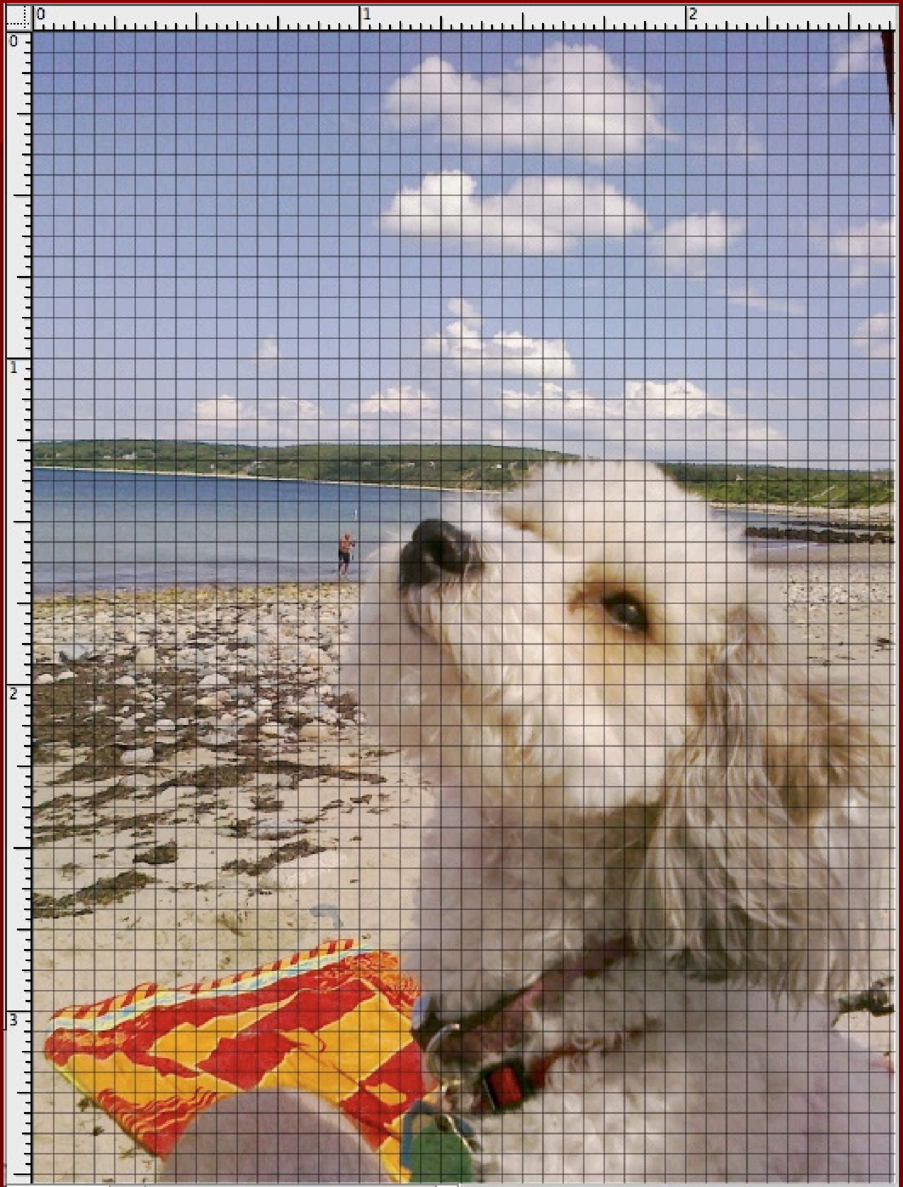
--Thomas A. Edison, 1888

Moving Pictures

How do you make moving pictures out of still images?

- Play enough images quickly enough to fool the mind into perceiving the images as continuous.
- Analogous to sampling by taking many successive pictures.

Recall: Digitizing an Image



Sampling:

Taking measurements (of color) at discrete locations within the image. (Spatial sampling)

Video:

In addition, sample at discrete time instances.

(Time sampling)

Frame Rate

The frame rate of a motion picture determines how life-like it looks.

- Television plays out at 30 frames/sec.
- 35 mm movie cameras use a standard of 24 frames/second.

At which frame rate do humans can see discrete pictures?

Data Requirements

Consider:

- 480 * 360 pixels (standard TV resolution)
- 3 bytes per pixel (TrueColor)

  = 518,400 bytes per frame
- 30 frames/second

  = 15,552,000 bytes per second

What about the audio?

Data Requirements

CD Audio Requirements:

- 16 bits per channel
- 44,100 samples/sec

  = 1,411,200 bits/sec = 176,400 bytes/sec

“TV + CD Audio” data requirements:

15,728,400 bytes per second

- This works out to about 14 megabytes per second of data
- A standard CD ROM holds about 700 MB, almost enough for 50 seconds of video + audio

But That’s Ridiculous!

Of course, the data requirements on the previous slides are ridiculous!

Why?

Compressing Video

Video compression is key to getting enough video onto a physical medium (e.g. DVD).

Video codec -- COmpressor/DECompressor
Algorithms used to shrink the size of a movie to allow it to be played on a computer or over a network.

Most codecs use **lossy** compression -- *why?*

Video Compression

Video is effectively a 3-dimensional array of pixels:

- Two spatial dimensions (width & height)
- One time dimension (across frames)

Video data contains spatial and temporal redundancy.

Spatial Compression

Based on removing redundant information within a frame.

- This is effectively what the JPG format does.
- JPEG can typically achieve 90% or 95% reduction in file image size without a visible loss in quality.

Temporal Compression

Based on differences between consecutive frames.

Example:

Ex 2: http://www.thedailyshow.com/watch/wed-june-6-2012/game-of-drones

Digital Video Formats

- MPEG-2 (standard definition DVD)
  - compresses video 15-30 times
- Quicktime
  - Incorporates Apple and open standard protocols for audio, images, video codecs
- MPEG-4
  - Enables streaming over networks
- Flash Video Player
  - Installed in about 95% of web browsers

Take-Away Points

- – Analog and Digital Information
- – RGB Color Encoding
- – Color Depth
- – Pixels and Resolution
- – Raster Graphics/Vector Graphics
- – Lossy vs. Lossless compression
- – Factors in image/video file size
- – Moving pictures
- – Codec
- – Temporal and spatial compression
- – Writing programs is easier with uncompressed data

Student To Dos

- Readings:
  - http://en.wikipedia.org/wiki/Computer_vision
  - http://en.wikipedia.org/wiki/Image_formats
  - http://en.wikipedia.org/wiki/Color_space