Computational Photography

* Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and interacting with photographs.

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Representing an Image

* What is a Digital Image?
* How to make an Image a Computable Entity

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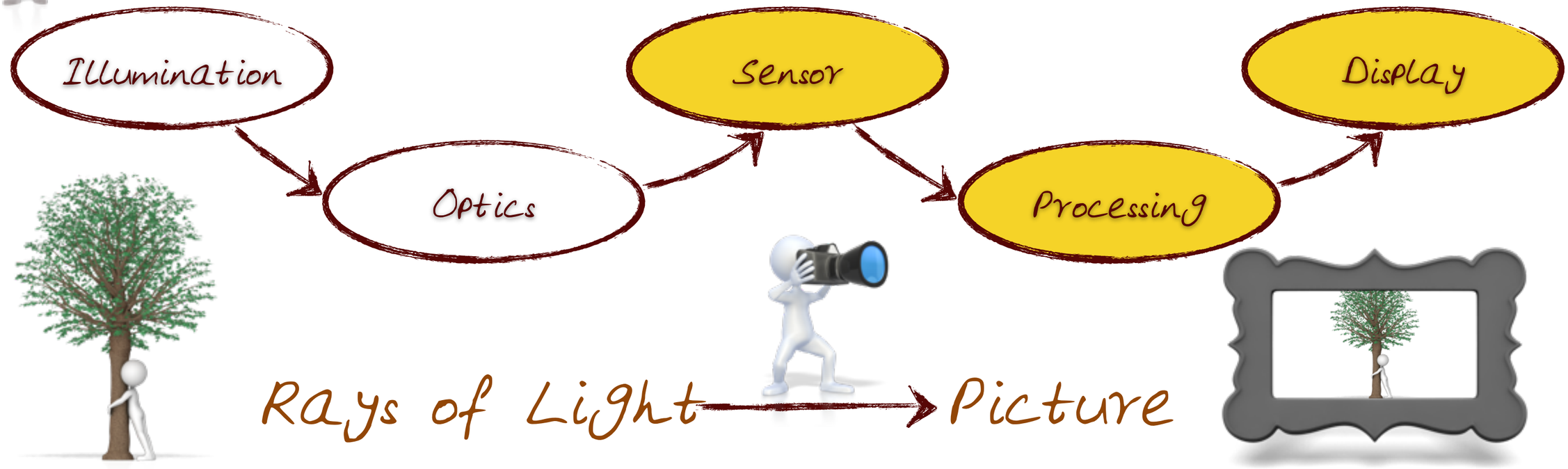
Recall the Comp. Photography Pipeline

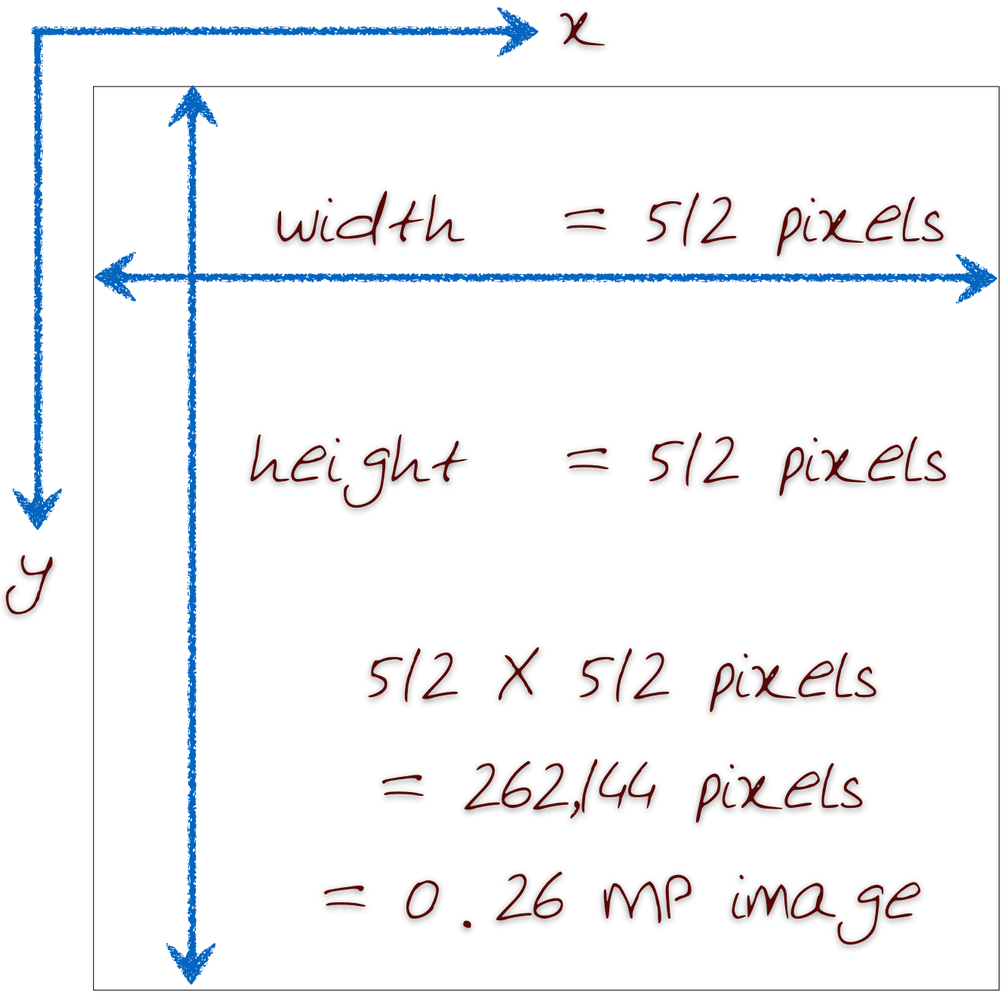


* make an Image a "computable" object
* ie., A Digital Image

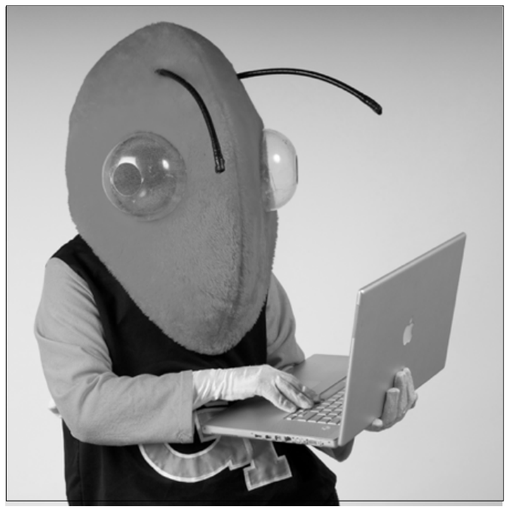
1. Digital Image - pixels and image resolution
2. Discrete (matrix) and Continuous (function) representations
3. Grayscale and Color Images
4. Digital Image formats

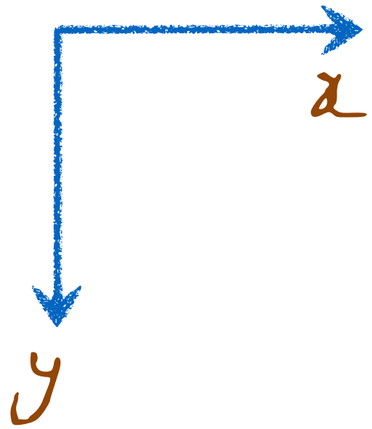
A Digital Image (W X H)

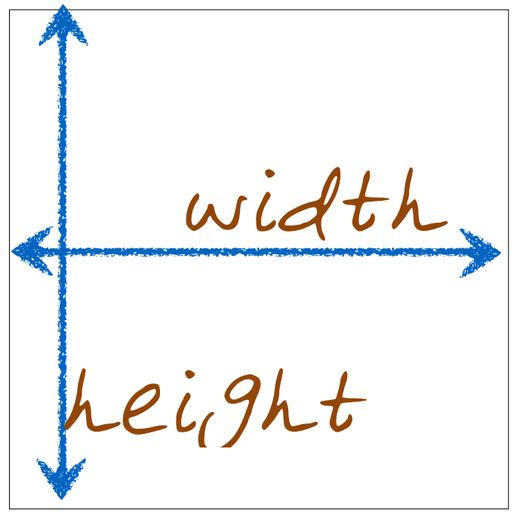
Georgia Tech's mascot Buzz in Black and White



A Digital Image!



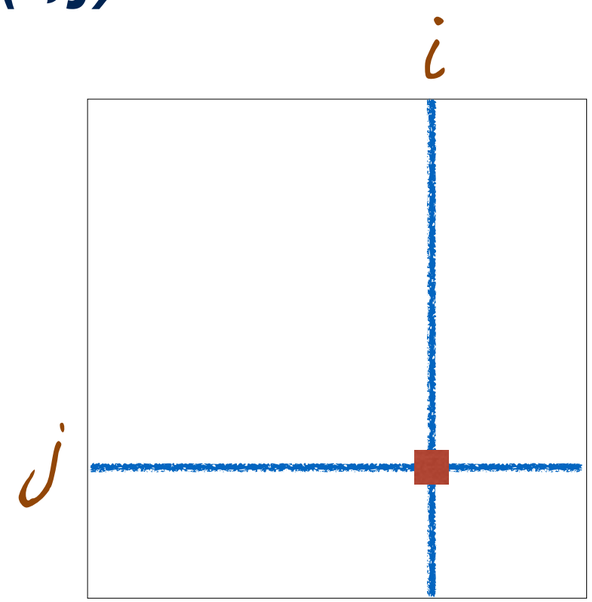




* Numeric representation in 2-D (x and y)
* Referred to as **I(x,y)** in continuous function form, **I(i,j)** in discrete
* Image Resolution: expressed in terms of Width and Height of the image

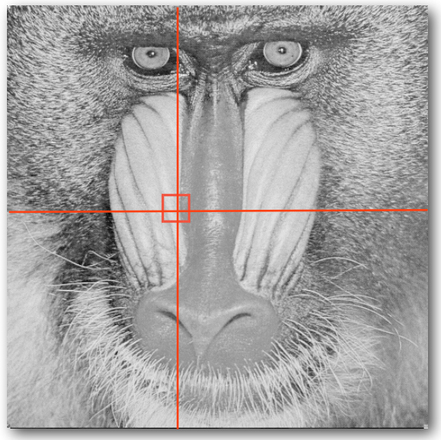
Pixel

A "**picture element**" that contains the light intensity at some location **(i,j)** in the image



I(i,j) = Some Numeric Value

Characteristics of a Digital Image

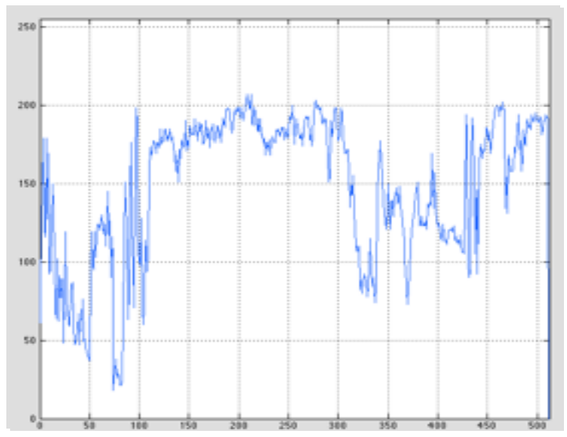


Original Image

Zoomed In

159	166	149	134	142	145	152	156
154	147	127	126	134	139	144	142
163	153	157	137	132	145	155	144
178	160	166	152	142	151	166	136
179	164	156	153	138	136	145	134
184	164	159	168	154	129	128	141
186	171	160	164	148	132	130	139
161	177	160	146	131	131	132	129
173	167	158	152	144	136	130	129
184	175	170	164	144	138	136	135
188	188	160	151	147	146	144	143
190	193	189	172	140	149	157	143
171	182	174	168	136	141	150	144

Values



Plots of Values at a Slice

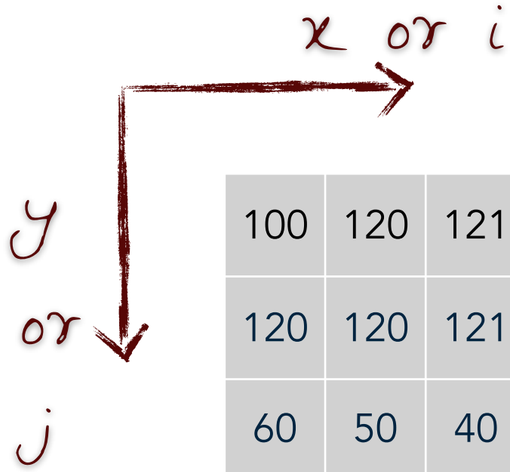
* A two-dimensional array of pixels and respective intensities
* Image can be represented as a matrix
* Intensity Values range from 0 = Black to 255 = White

Common data types

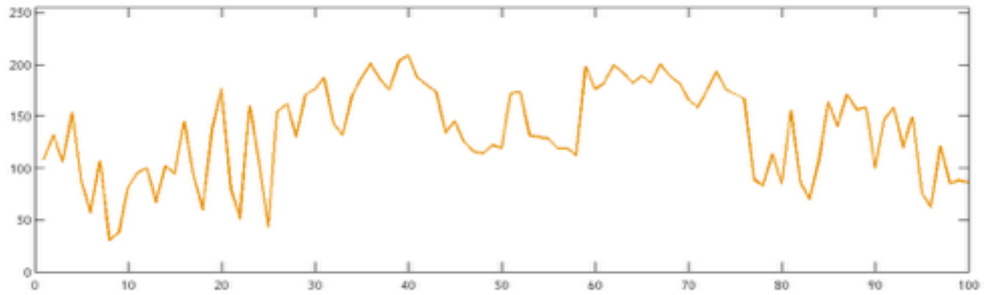
Data types used to store pixel values:

- unsigned char
- uint8
- unsigned char 8bit
- 2^n (2^1, 2^2, 2^4, 2^8, etc.)

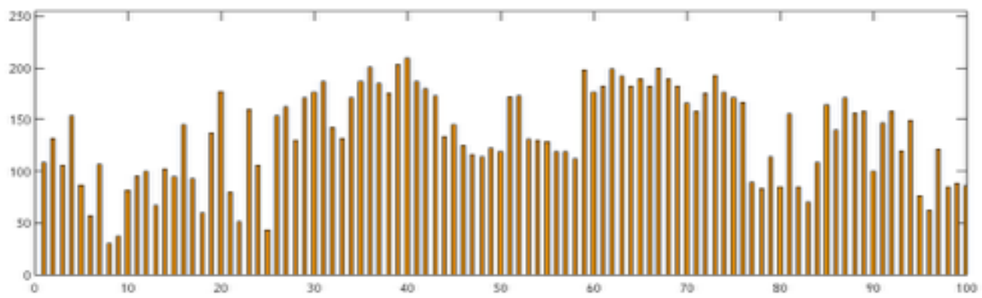
Digital Image is a Function



100	120	121	122	30	40
120	120	121	122	70	40
60	50	40	41	7	8
100	120	121	122	1	0
200	120	200	122	12	14
200	220	225	250	30	40



Continuous Signal



Discrete Signal

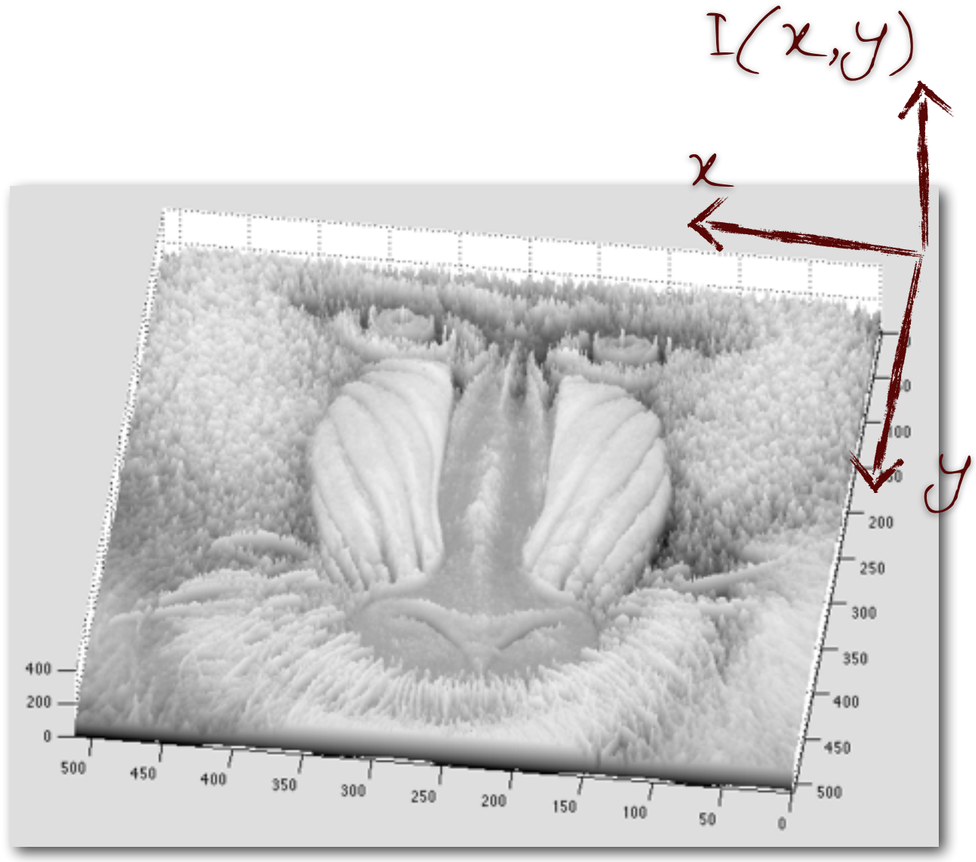
Slide adapted from Steve Seitz and Aaron Bobick

Digital Image is a Function

x or i

y or j

100	120	121	122	30	40
120	120	121	122	70	40
60	50	40	41	7	8
100	120	121	122	1	0
200	120	200	122	12	14
200	220	225	250	30	40



Slide adapted from Steve Seitz and Aaron Bobick

Digital Image is a Function

100	120	121	122	30	40
120	120	121	122	70	40
60	50	40	41	7	8
100	120	121	122	1	0
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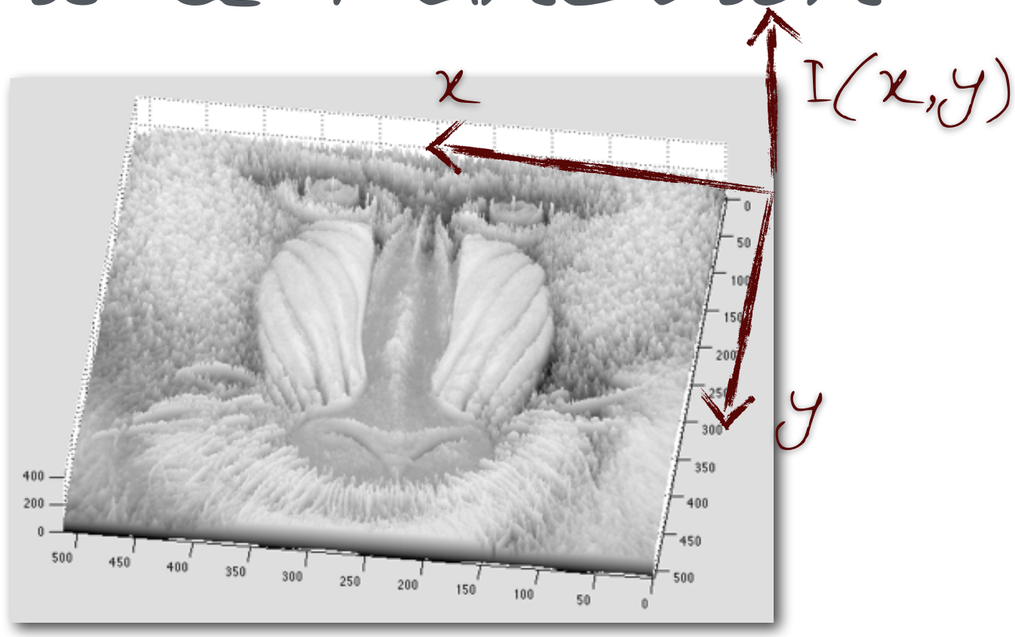
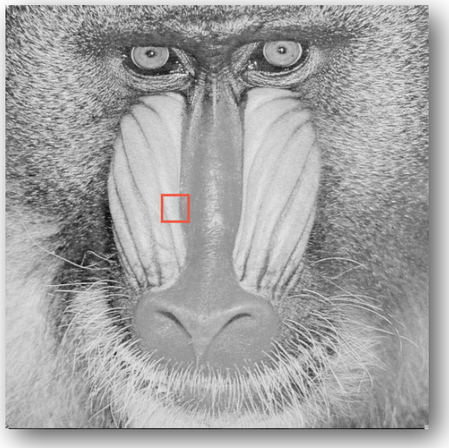
200	220	225	250	30	40



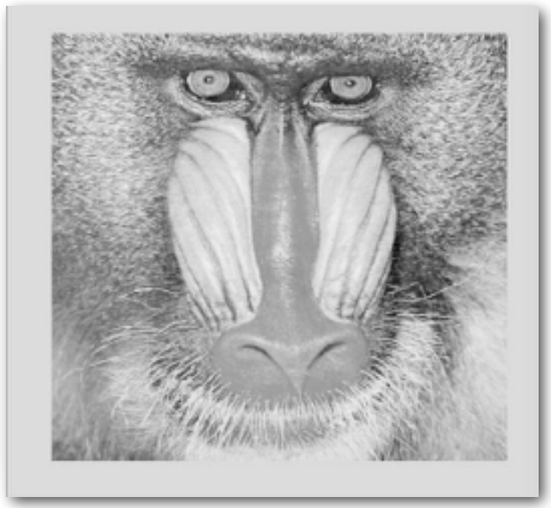
- Typically, the functional operation requires discrete values
  - Sample the two-dimensional (2D) space on a regular grid
  - Quantize each sample (rounded to "nearest integer")
- matrix of integer values (Range: 0-255)

Slide adapted from Steve Seitz and Aaron Bobick

Black/White Digital Image: An Example



Image



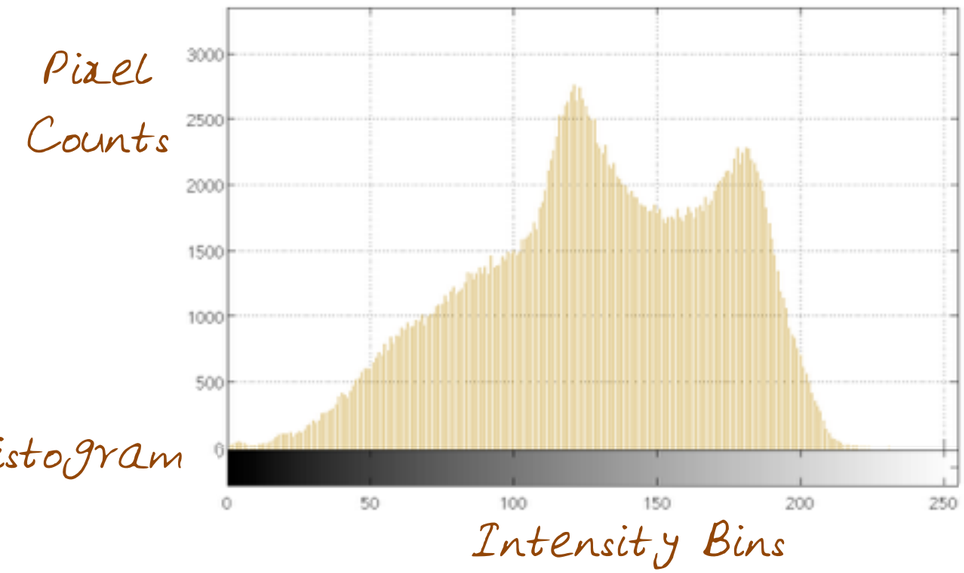
Height Map

Height Map

Zoomed In

Using matlab

Digital Image Statistics



- Image statistics - average, median, mode
  - Scope - entire image or smaller windows/regions
- Histogram - distribution of pixel intensities in the image
  - Can be separate for each channel, or region-based too

Color Digital Image: An Example

Color Red Channel Green Channel Blue Channel

- Color image = 3 color channels (images, with their own intensities) blended together
- Makes 3D data structure of size: Width X Height X Channels
- Each pixel has therefore 3 intensities: Red (R), Green (G), Blue (B)

Digital Image Formats

Raster image formats store a series of colored dots "pixels"

Number of bits for each pixel represents the depth of color

- 1 bit-per-pixel: 2 colors (black or white, binary)
- 4 bits-per-pixel: 16 colors
- 8 bits-per-pixel: 256 different colors

Digital Image Formats

Images can also be 16, 24, 32 bits-per-pixel:

- 24 bits per pixel usually means 8 bits per color
- At the two highest levels, the pixels themselves can carry up to 16,777,216 different colors

Common raster image formats:

- GIF, JPG, PPM, TIF, BMP, etc.
- Will discuss Camera RAW format later

Exercises to do on your own

- matlab
  - (mathworks.com)
- OpenCV/Python
  - (opencv.org, python.org)
- Processing
  - (processing.org)

Exercises: Read and write images

In Python-OpenCV:

```
> import cv2
> img = cv2.imread('input.png')
> cv2.imwrite('output.png', img)
```

Exercises: Read and write images

In matlab:

```
> img = imread('input.png')
> imwrite('output.png', img)
```

Other functions to consider:

```
> imshow(img)
> imageinfo('input.png')
> help images
```

Extract image properties

Read image, then find out:

- Dimensions of the image
- Number of color channels
- Bits per pixel

```
> print img.shape % (w, h, #channels)
> print img.dtype % NumPy types
```

Understand image formats

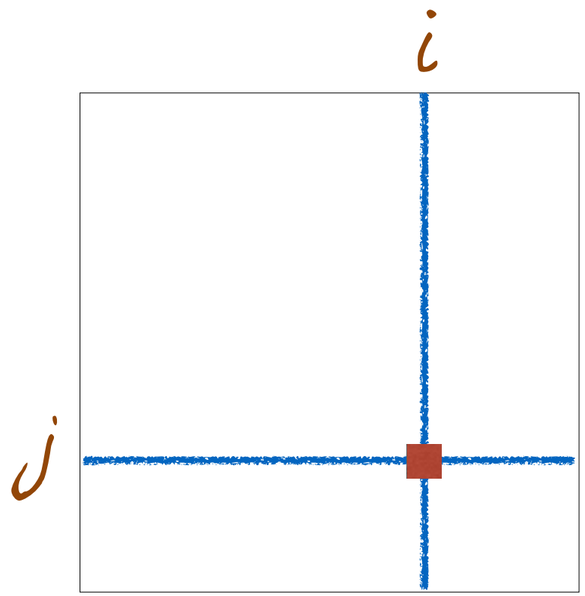
- Order of color channels
- Image compression information
- metadata about pictures
  (Exchangeable Image File Format:
  EXIF, etc.)

Summary

- Digital Image, and how it can be made into a computable object.
- Different formats of images using examples of black/white and color images.
- Introduced histograms, and simple computational methods over images to compute image statistics.

Next!

Digital Image: Processing and Filtering



Credits

- matlab software by Mathworks Inc.
- Some slides adapted from Steve Seitz and Aaron Bobick
- Mandrill Image from Signal and Image Processing Institute, University of Southern California,
  - http://sipi.usc.edu/database/download.php?vol=misc&img=4.2.03
- Georgia Tech's mascot Buzz image, courtesy Georgia Tech.