

Computational Photography



Dr. Irfan Essa

Professor

School of Interactive Computing



Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.



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What is a Digital Image?

How to Make an Image a Computable Entity

Lesson Objectives

- ★ Describe what is a Digital Image using the terms pixels and image resolution.
- ★ Describe why we need a Discrete (matrix) Representation of an Image over a Continuous (function) one.
- ★ Using correct terminology, explain how Black/White and Color Images can be digitally represented to allow for both Processing and Computation over those Images.
- ★ Identify at least four characteristics of Digital Image formats that should always be considered when making an Image computable.



What is a Digital Image?



Georgia Tech's Mascot Buzz

- ★ “Digital” Image:
 - numeric representation in two-dimensions (x and y)
 - referred to as $I(x,y)$ in continuous function form, $I(i,j)$ in discrete
- ★ Image Resolution:
 - expressed as representation of Width and Height of the image.
- ★ Each pixel (picture element) contains light intensities for each value of x and y of $I(x,y)$.

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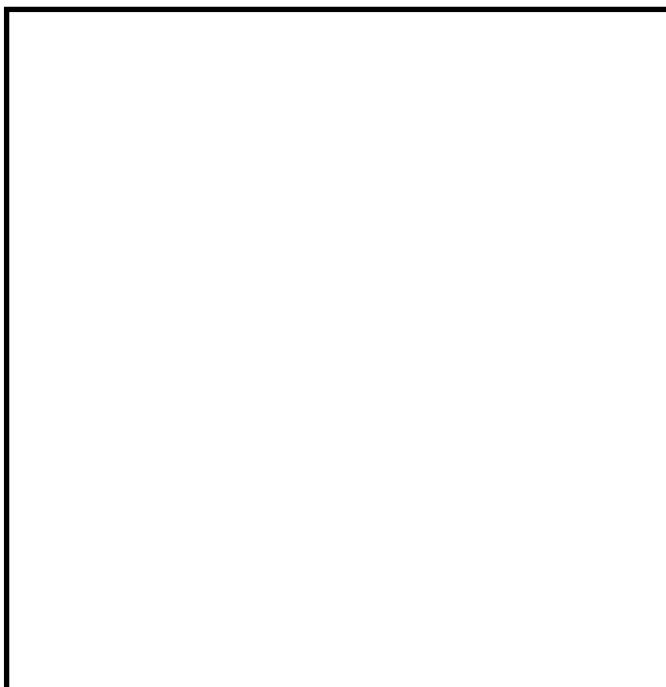
Georgia Tech's Mascot Buzz, in Black and White

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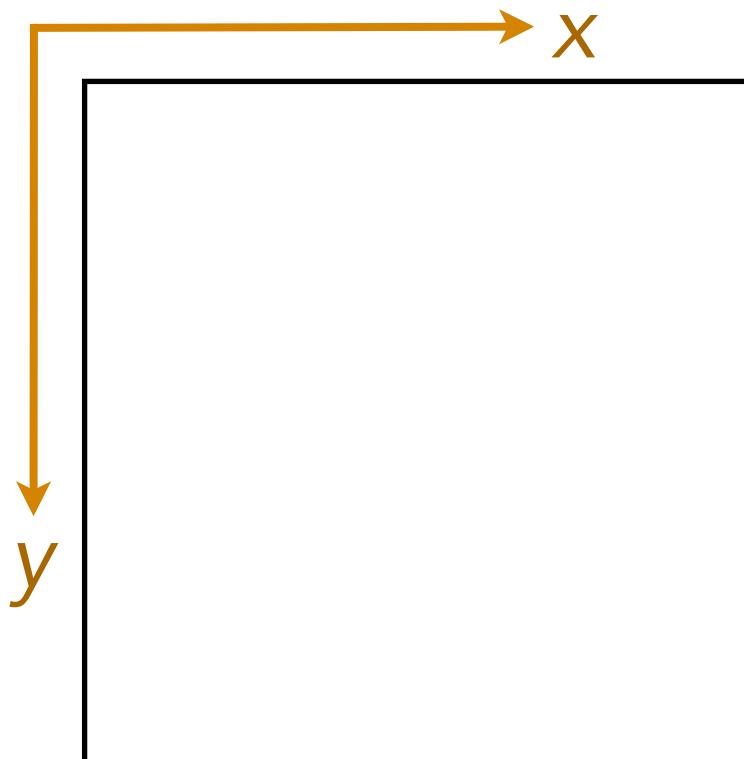


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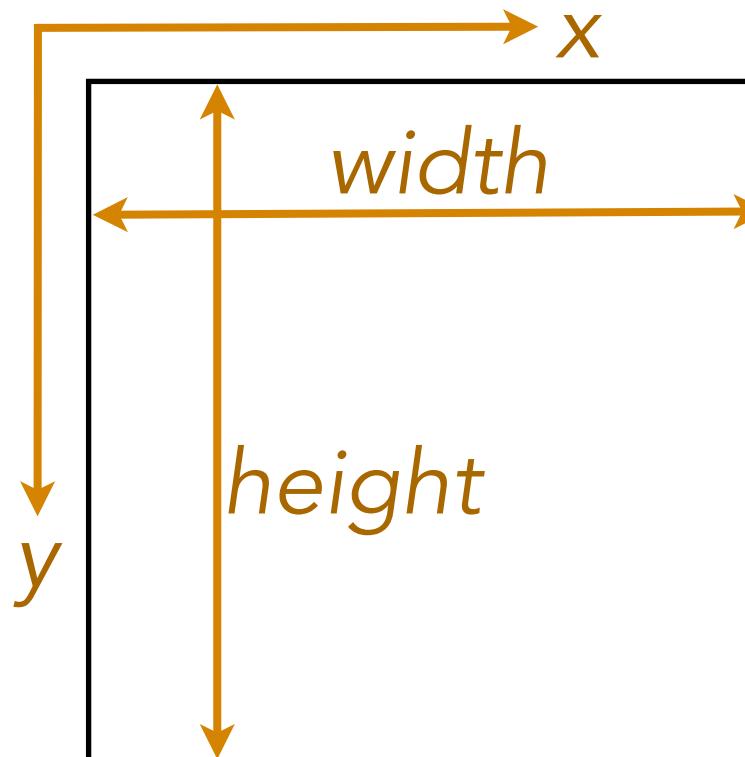


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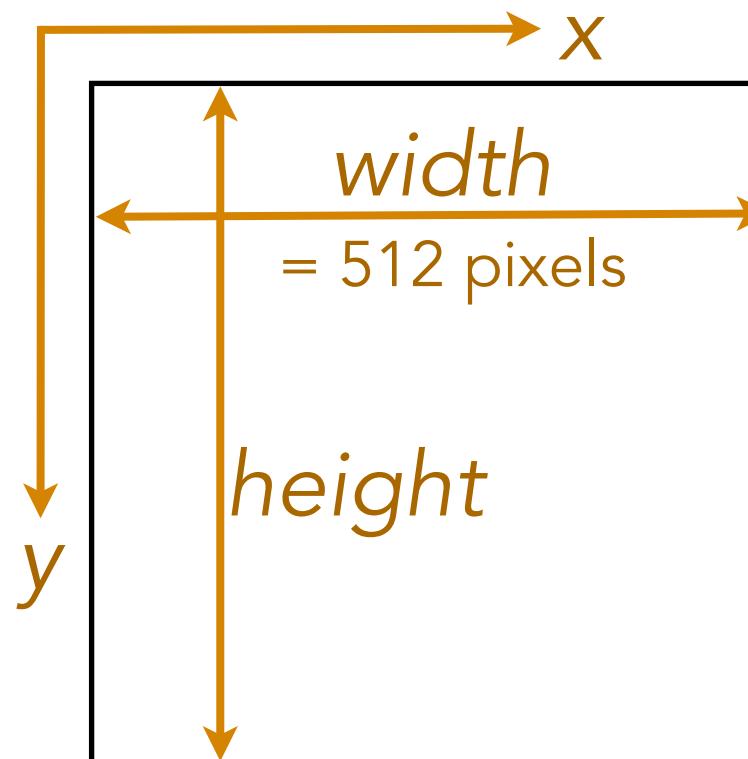


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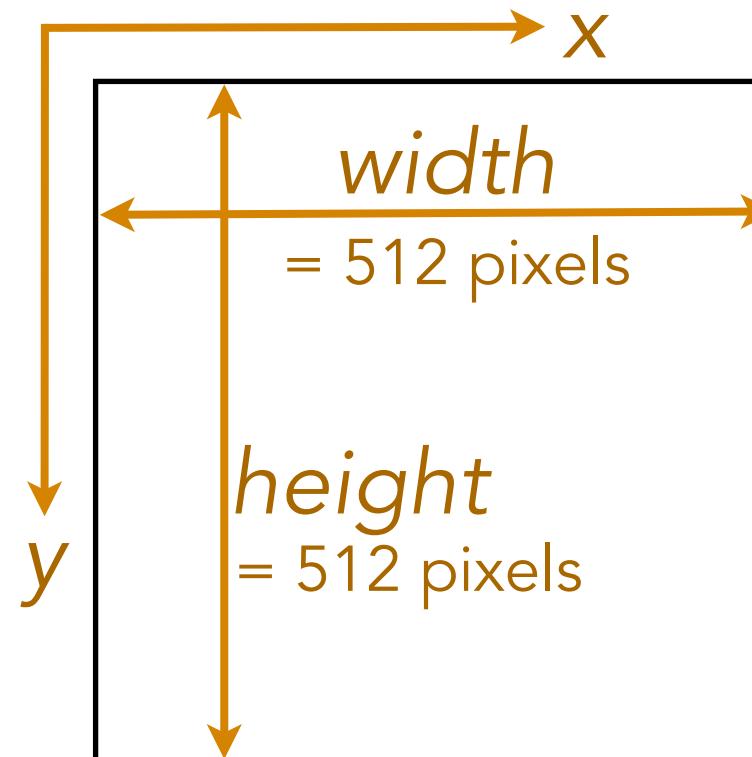


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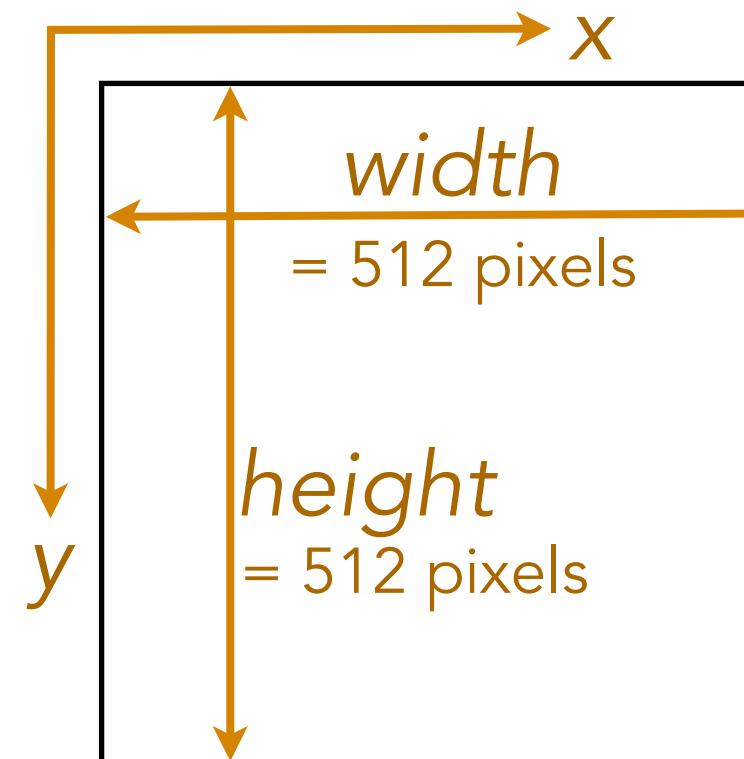


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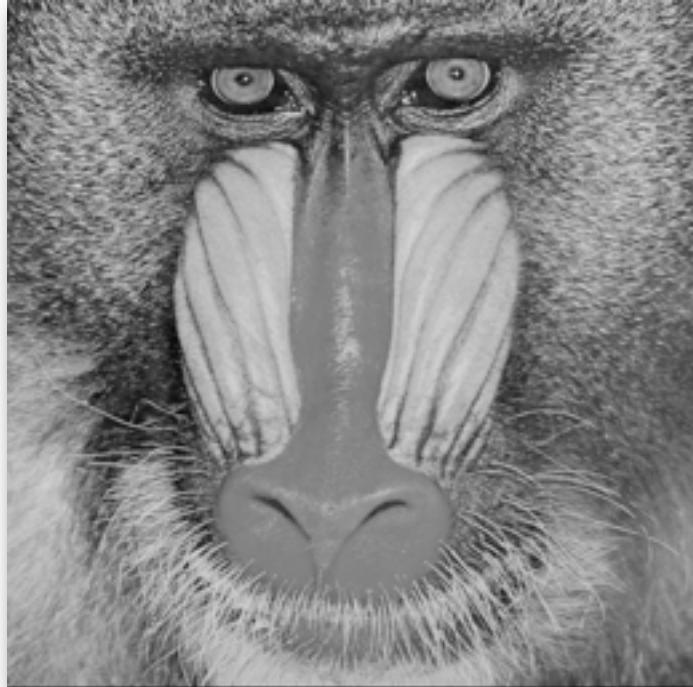
Georgia Tech's Mascot Buzz, in Black and White



512x512 pixels
= 262,144 pixels
= .26 MP image

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Characteristics of a Digital Image



Original Image

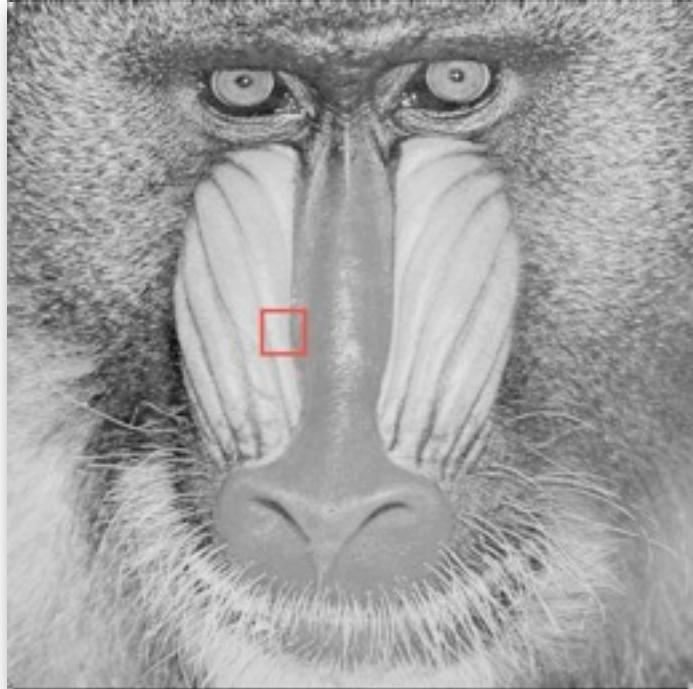
Zoomed In

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 (B) to 255=White (W)
- ★ Image is usually represented in unsigned char (or uint8;
unsigned char 8bit) format

Characteristics of a Digital Image



Original Image

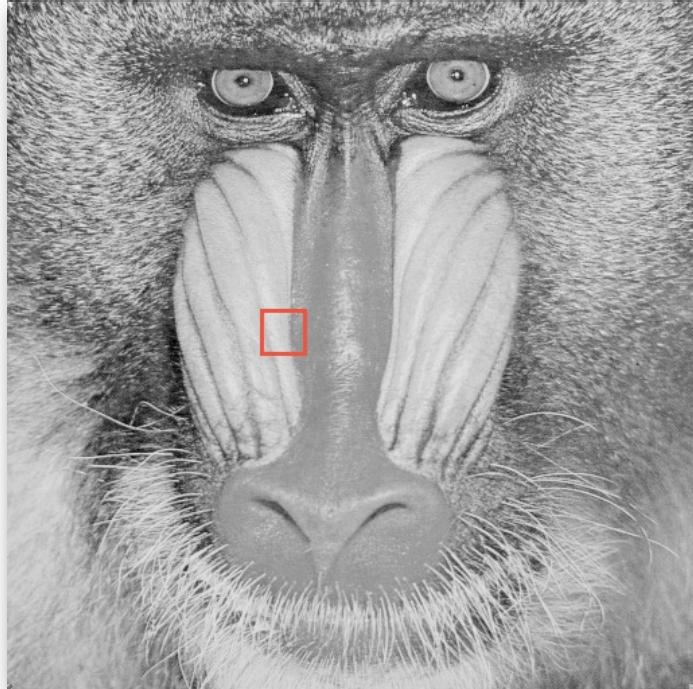
Zoomed In

Values

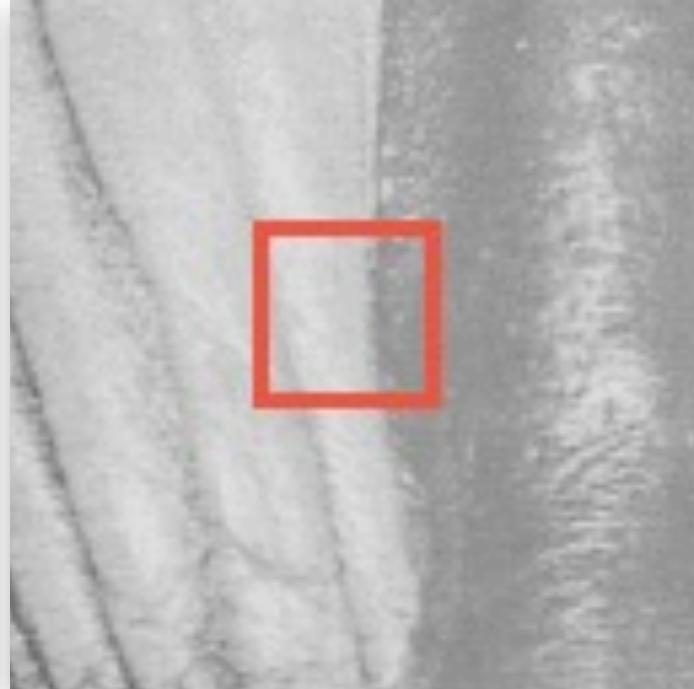
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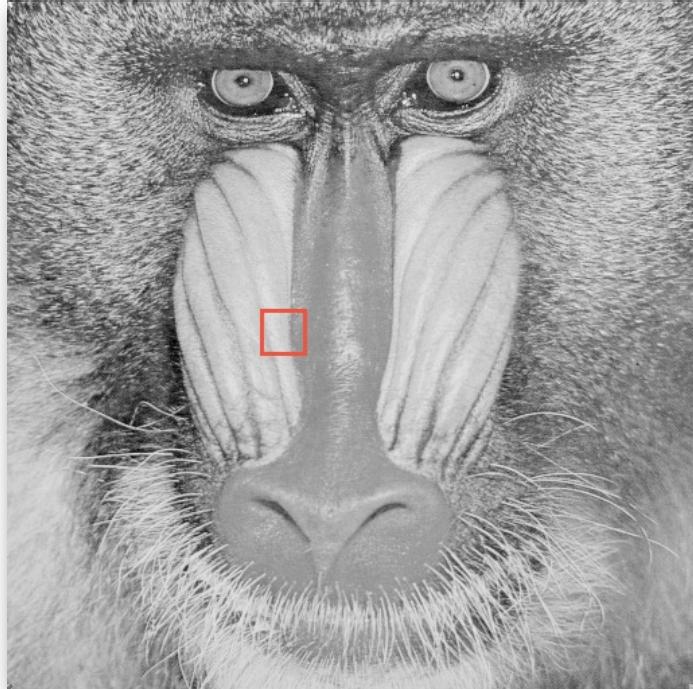
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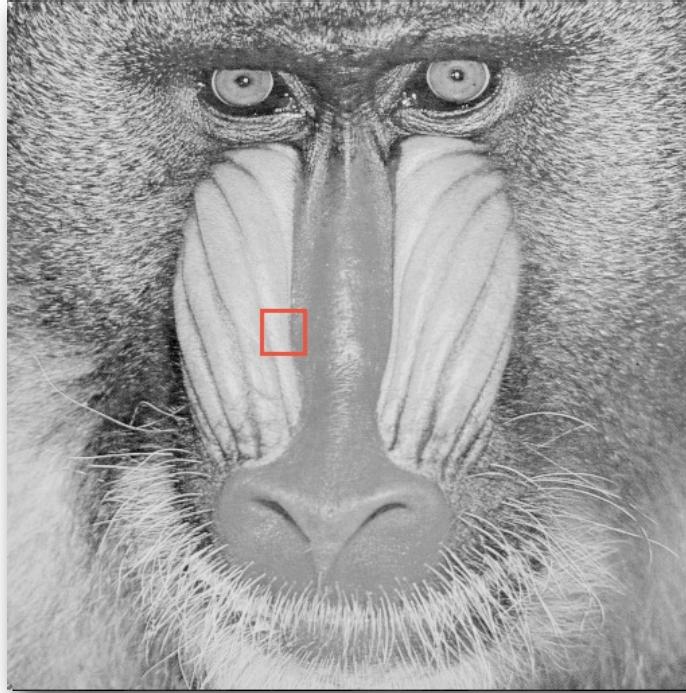
Zoomed In

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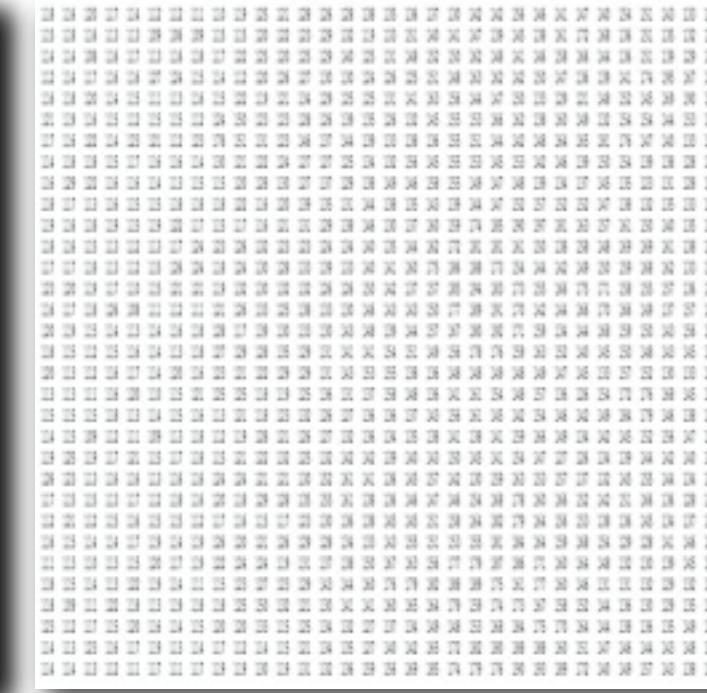
Characteristics of a Digital Image



Original Image



Zoomed In

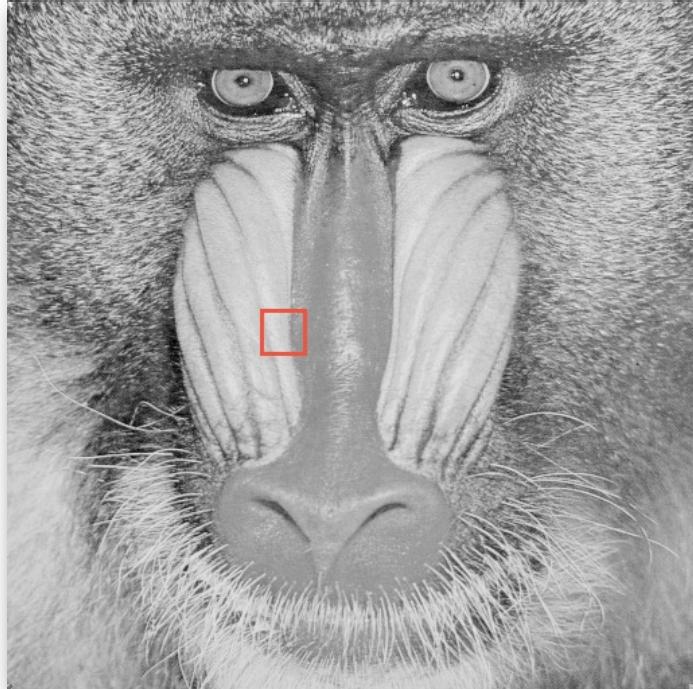


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Characteristics of a Digital Image



Original Image



Zoomed In

151	131	123	146	137	144	139	133
121	122	124	127	127	125	134	132
120	128	130	127	137	129	138	149
122	116	120	139	135	131	144	138
117	116	121	131	129	138	146	130
126	132	123	123	124	134	140	135
124	130	128	133	139	133	140	141
132	130	132	132	126	126	150	142
131	130	131	130	130	130	147	137

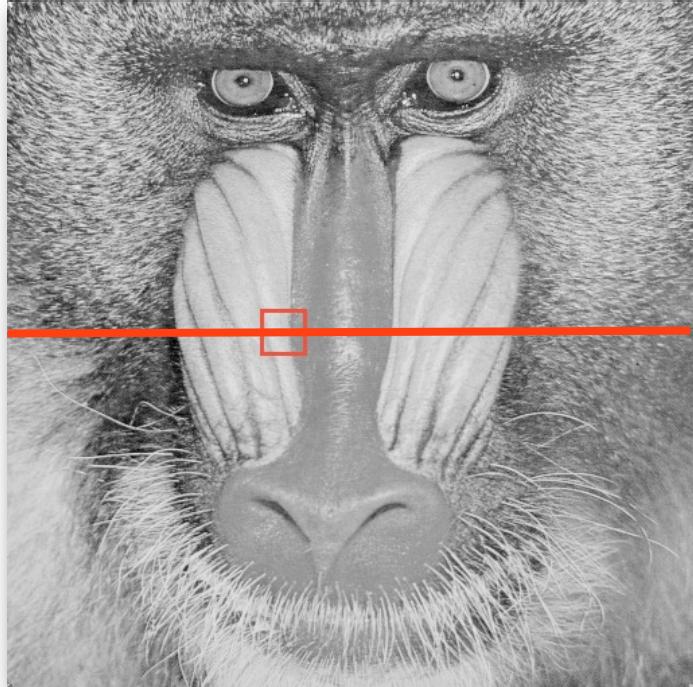
Values

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A careful observer may note that this image does not match what was described in the lecture.
-- IE

Characteristics of a Digital Image



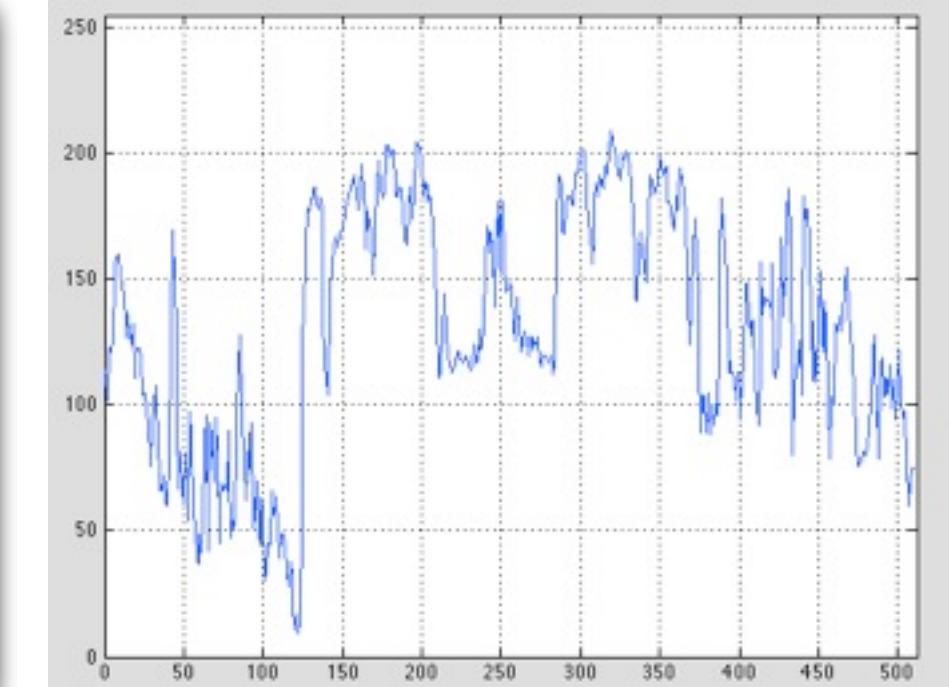
Original Image



Zoomed In

151	131	123	146	137	144	139	133
121	122	124	127	127	125	134	132
120	128	130	127	137	129	138	149
122	116	120	139	135	131	144	138
117	116	121	131	129	138	146	130
126	132	123	123	124	134	140	135
124	130	128	133	139	133	140	141
132	130	132	132	126	126	150	142

Values

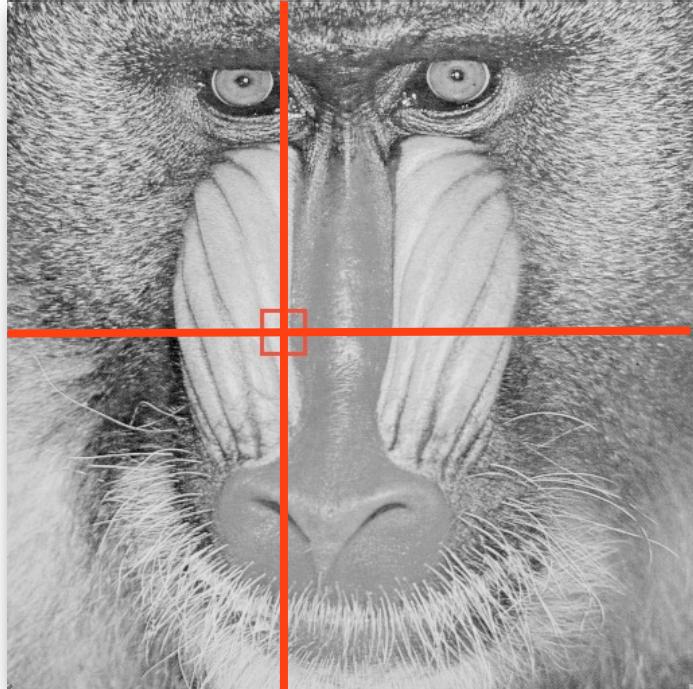


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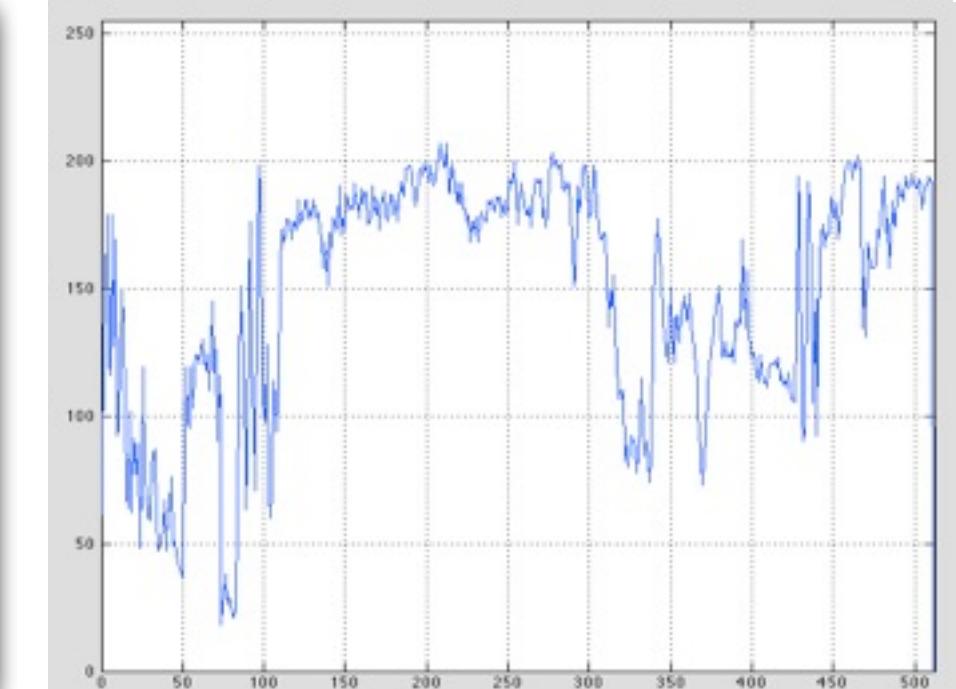
Original Image



Zoomed In

151	131	123	146	137	144	139	133
121	122	124	127	127	125	134	132
120	128	130	127	137	129	138	149
122	116	120	139	135	131	144	138
117	116	121	131	129	138	146	130
126	132	123	123	124	134	140	135
124	130	128	133	139	133	140	141
132	130	132	132	126	126	150	142

Values

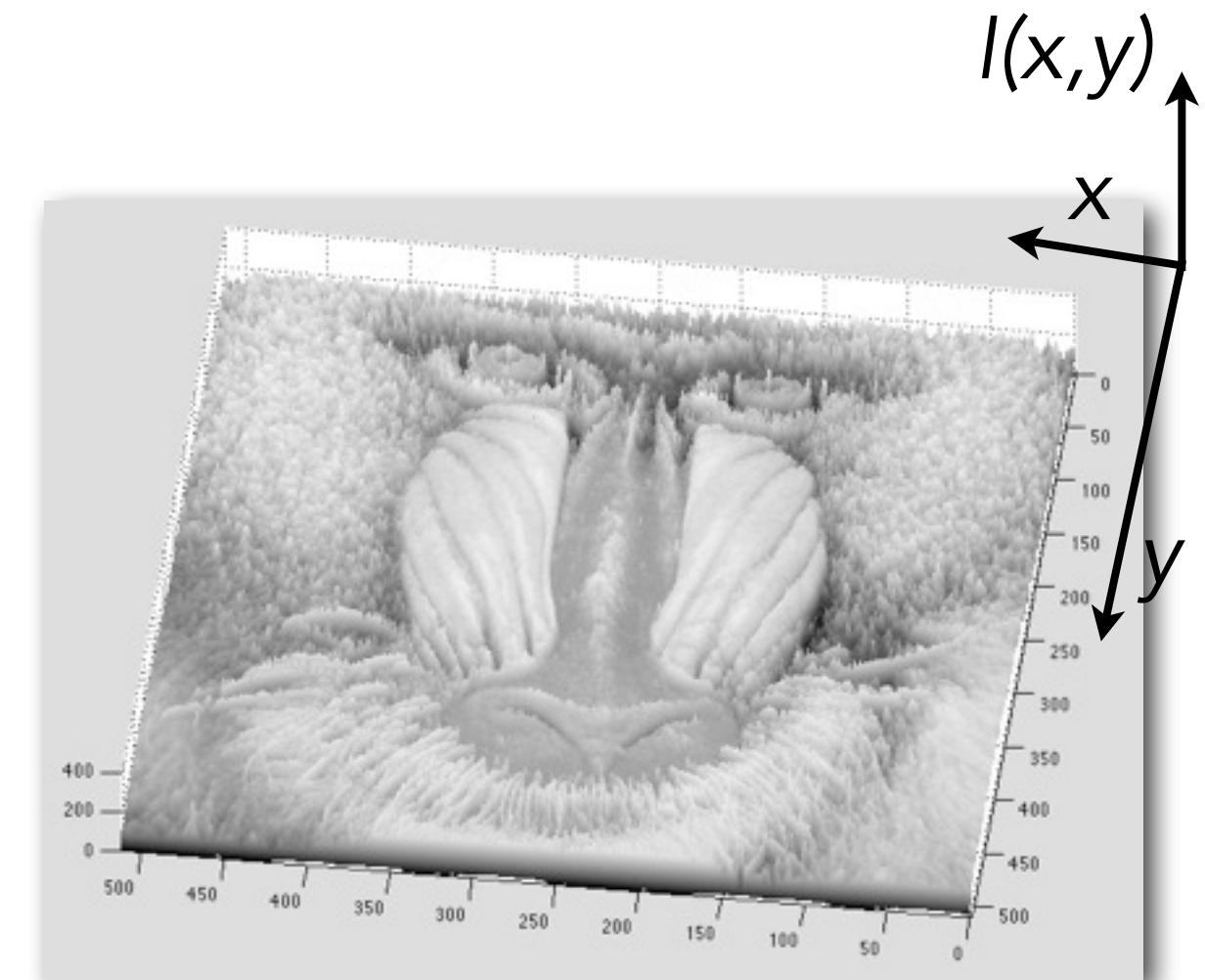
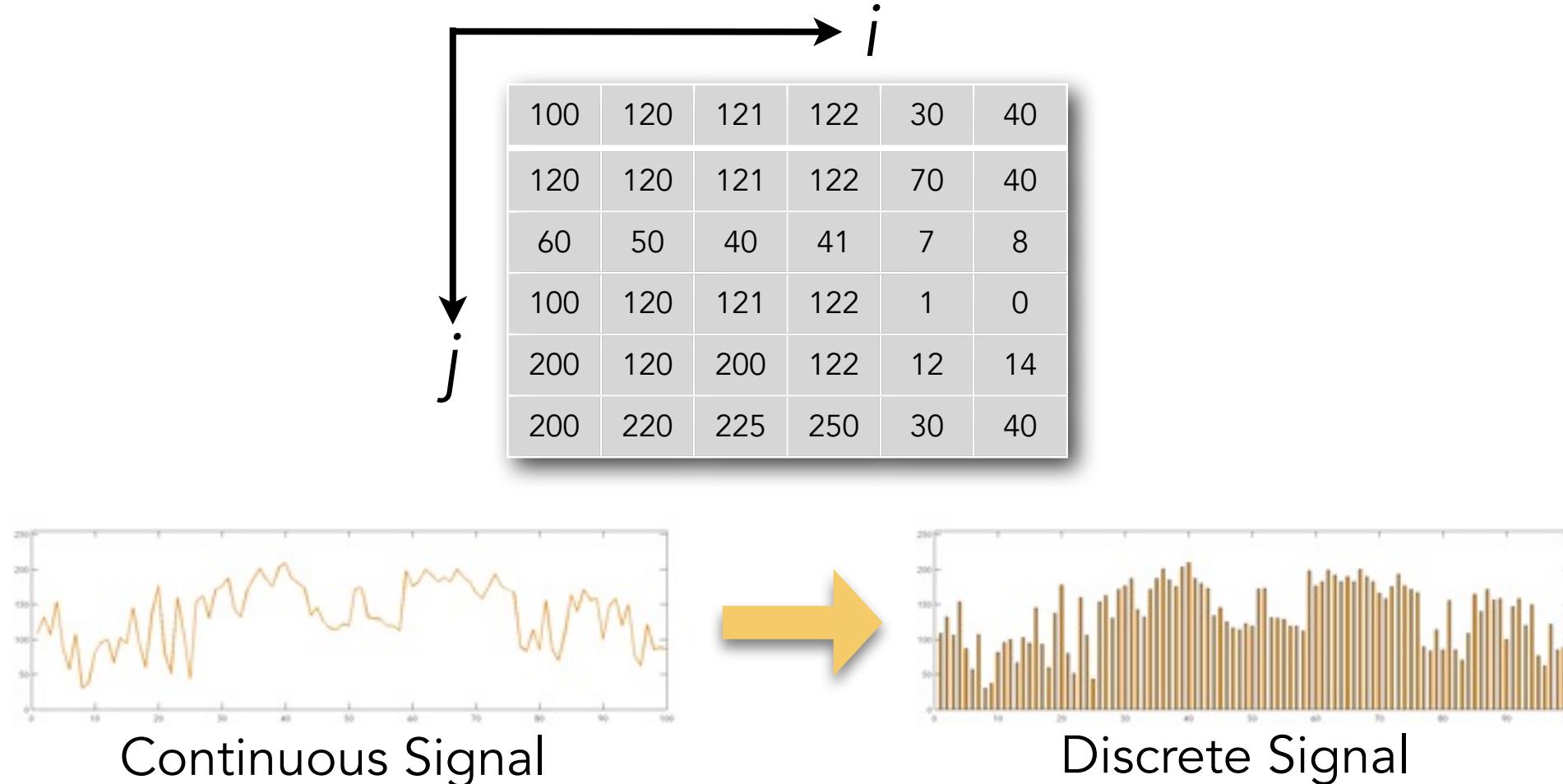


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-- IE

Digital Image is a Function



- ★ 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)

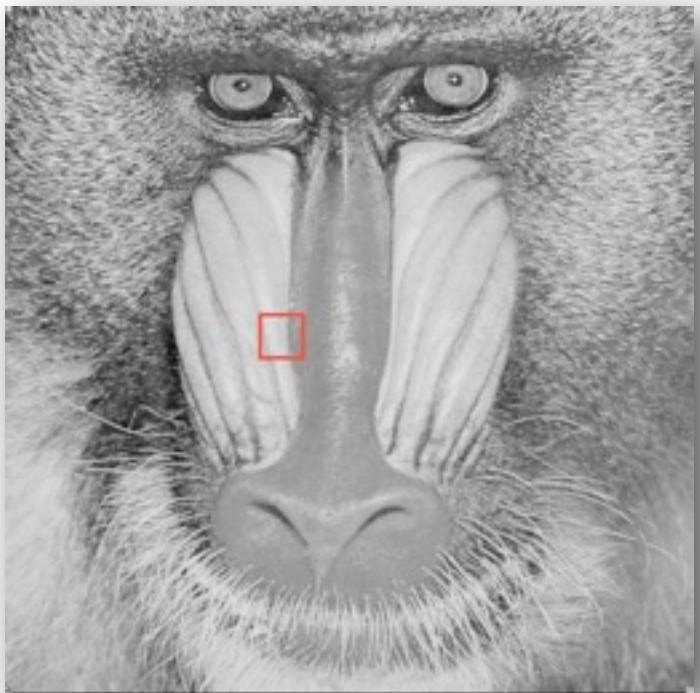
Slide adapted from Steve Sietz and Aaron Bobick

Black/White Digital Image: An Example

Image

Height Map

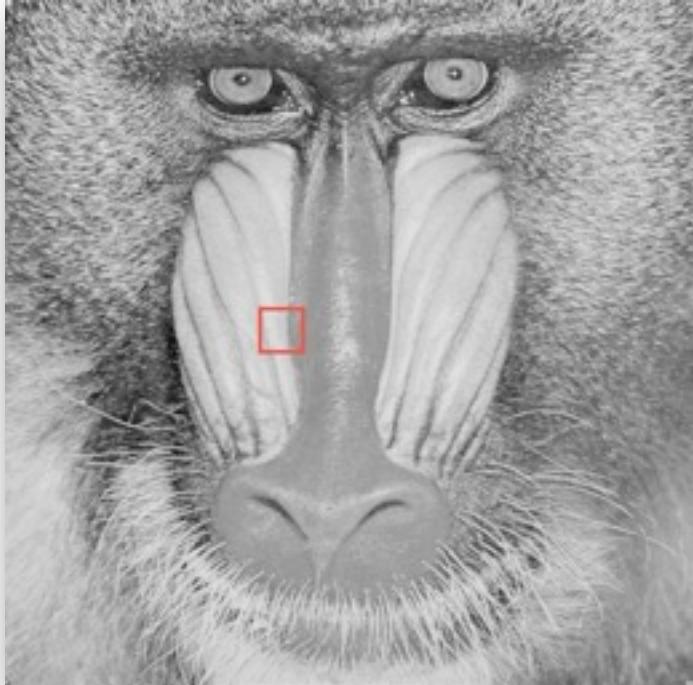
Black/White Digital Image: An Example



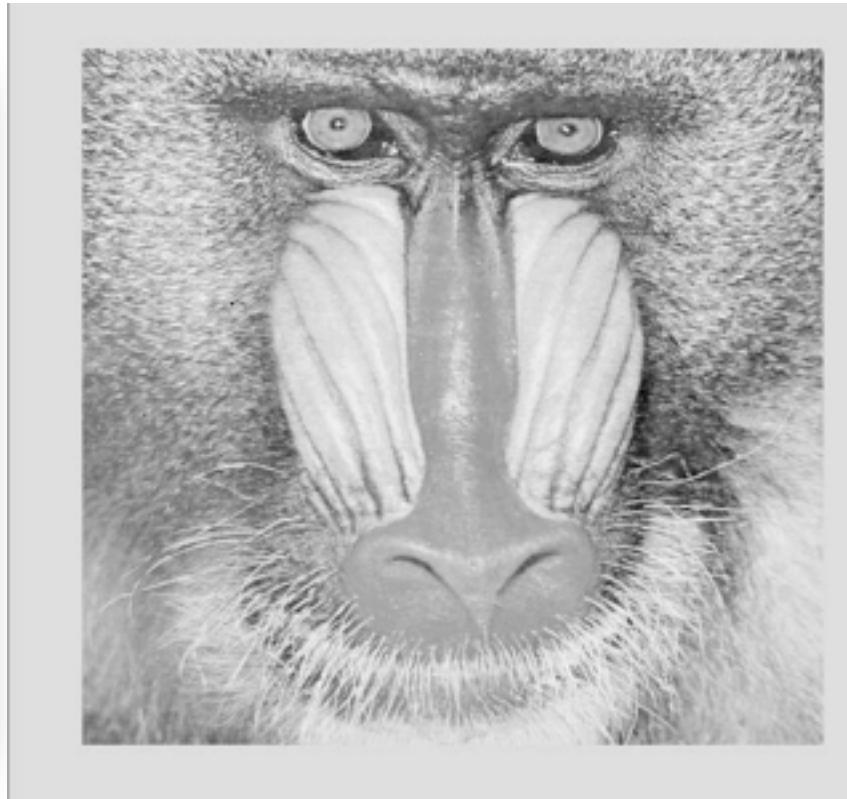
Image

Height Map

Black/White Digital Image: An Example

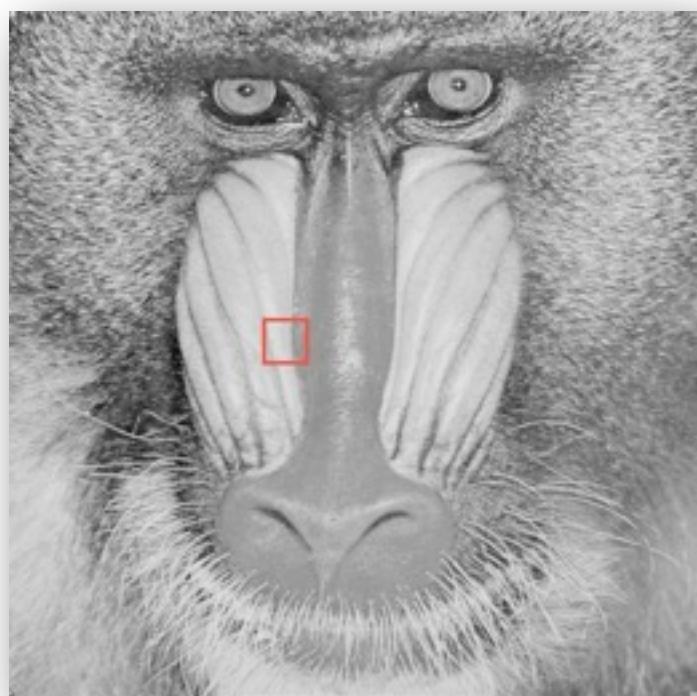


Image

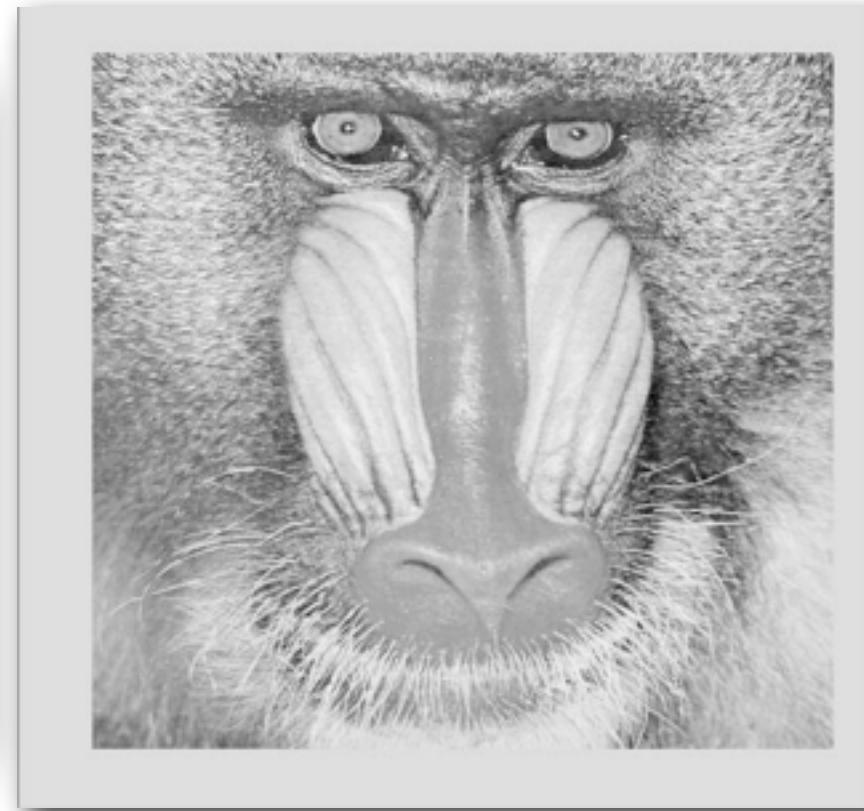


Height Map

Black/White Digital Image: An Example

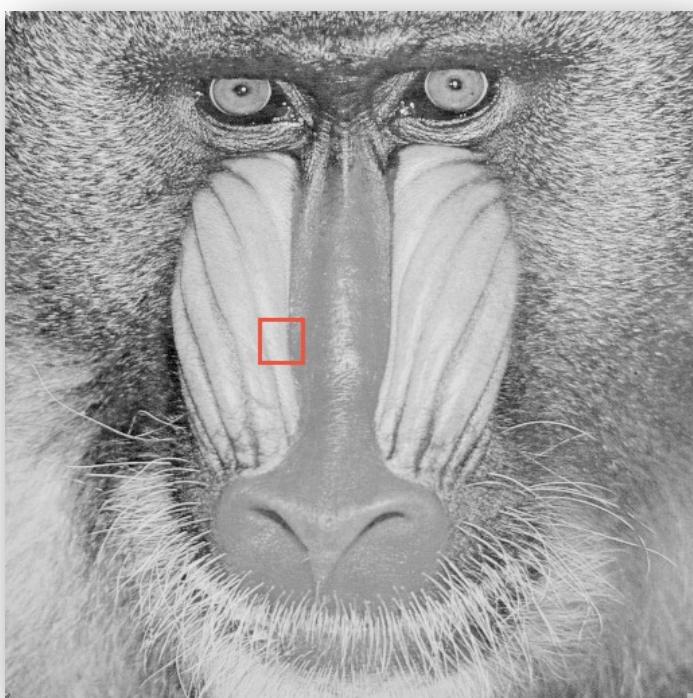


Image

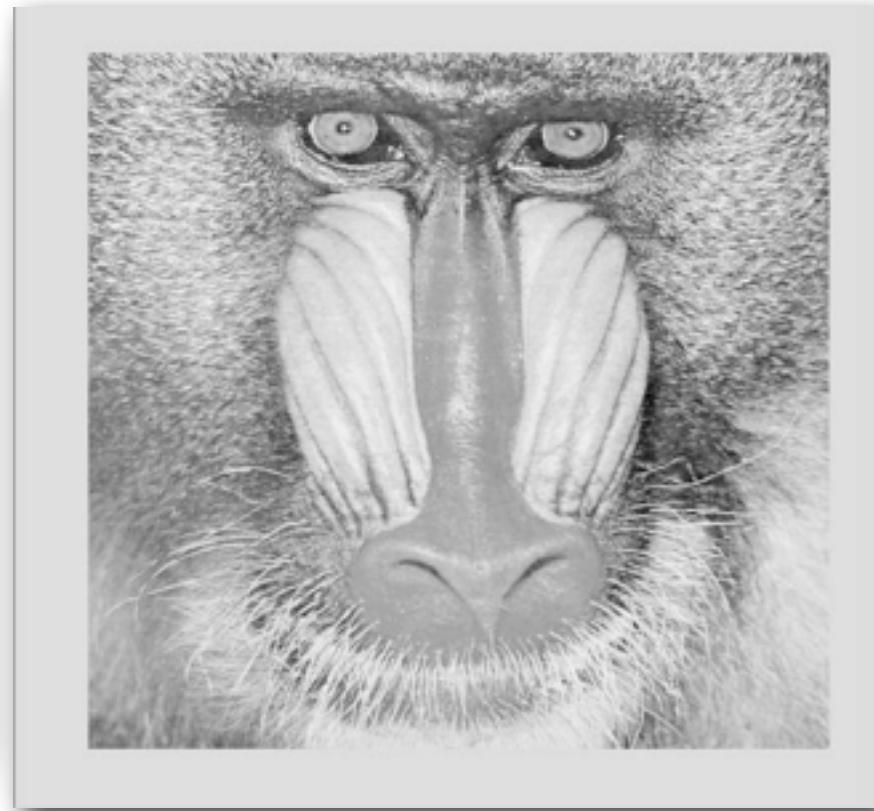


Height Map

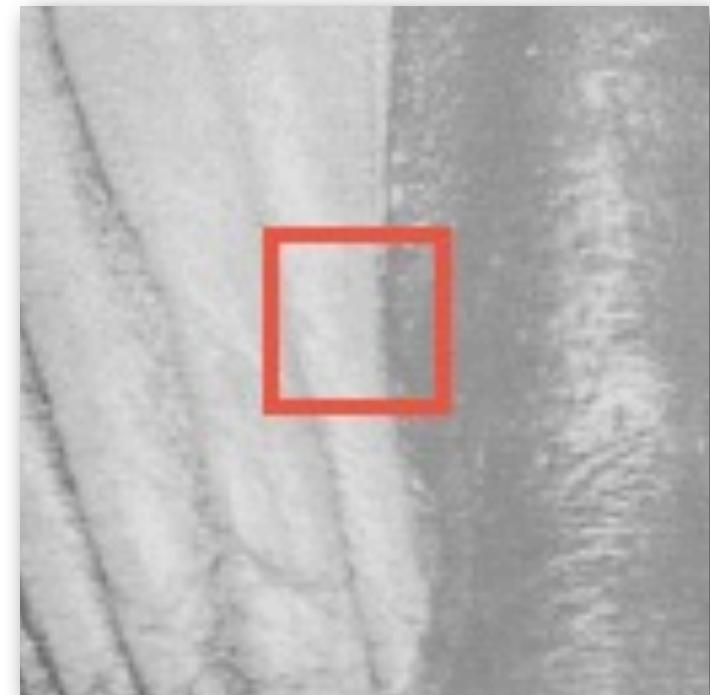
Black/White Digital Image: An Example



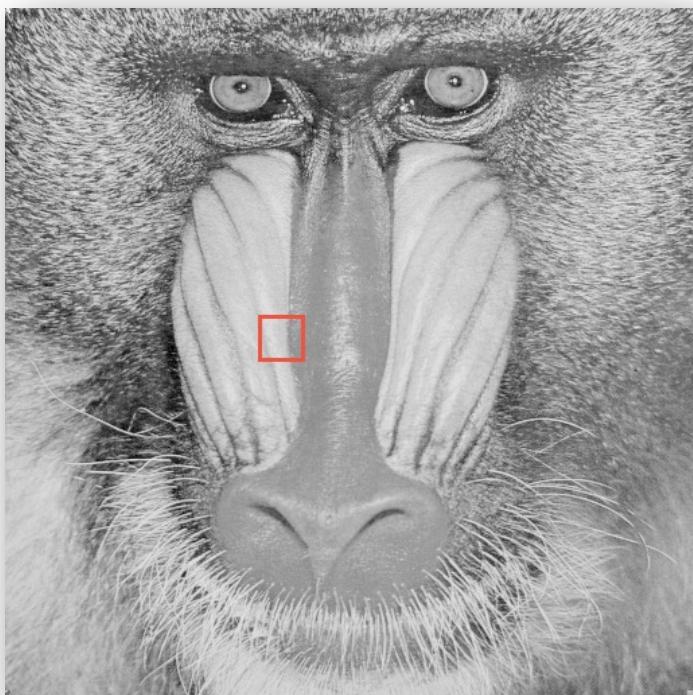
Image



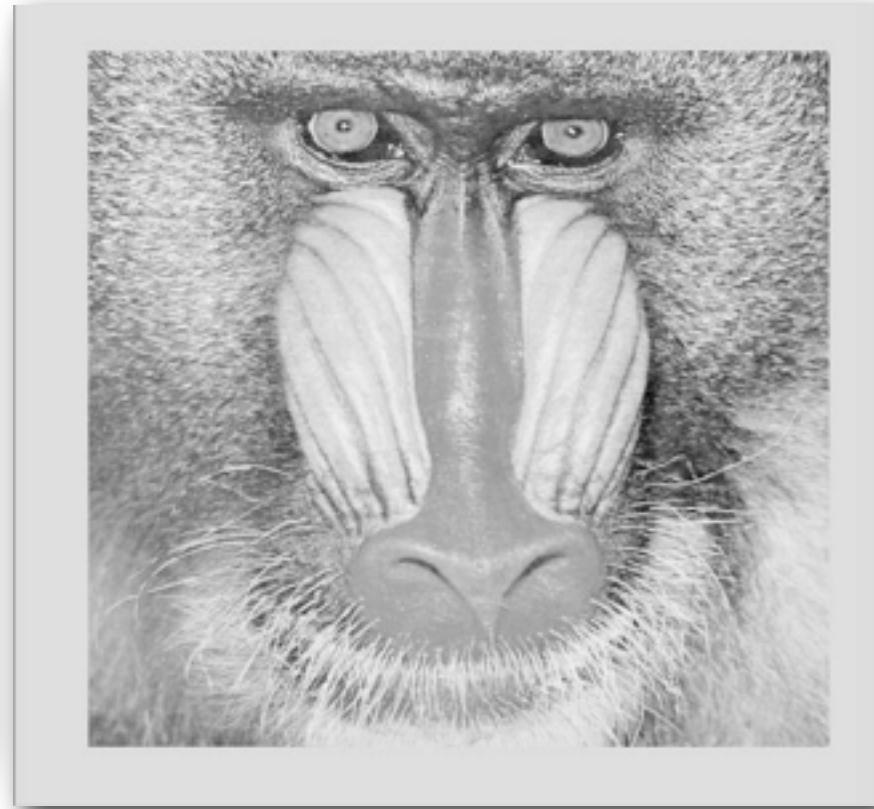
Height Map



Black/White Digital Image: An Example



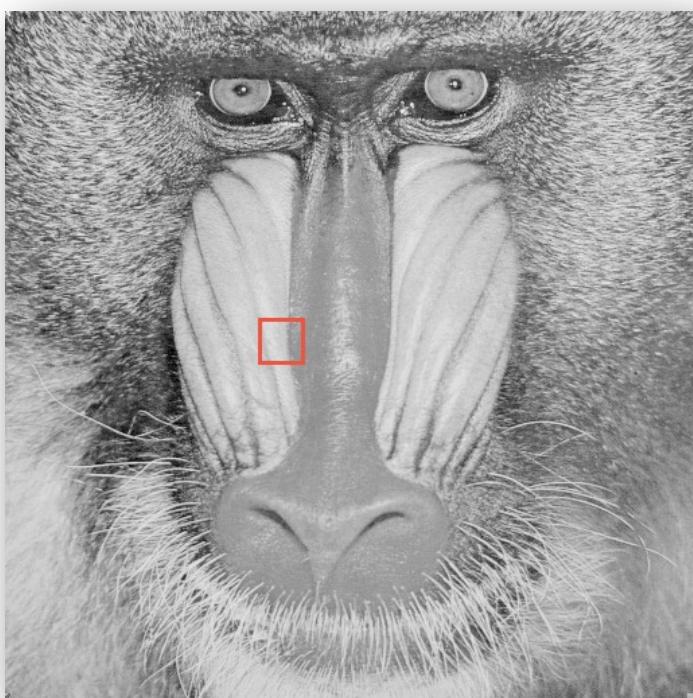
Image



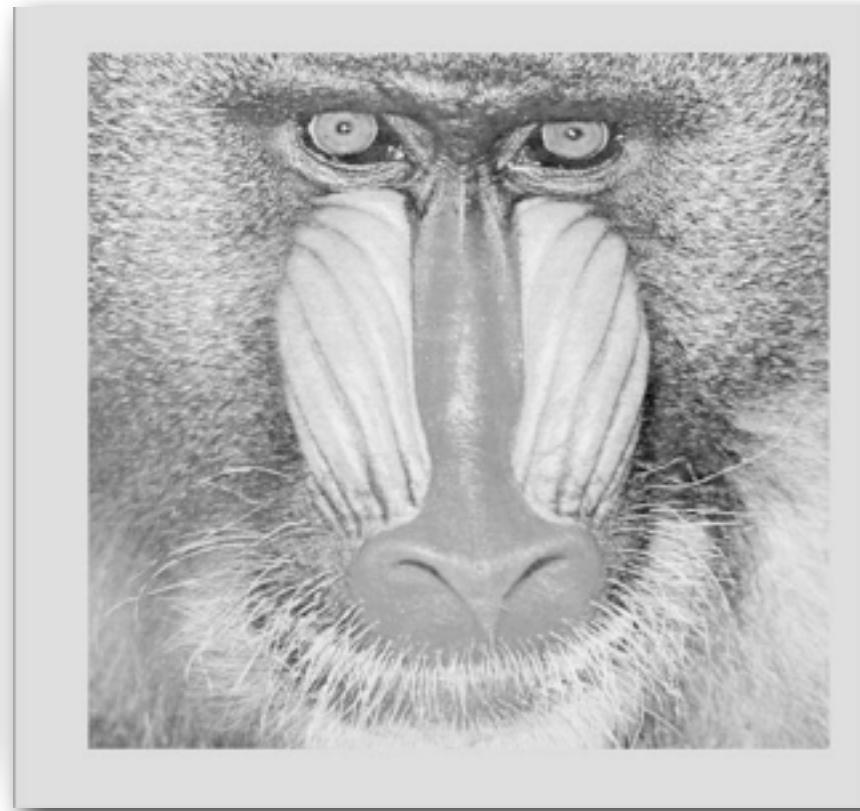
Height Map



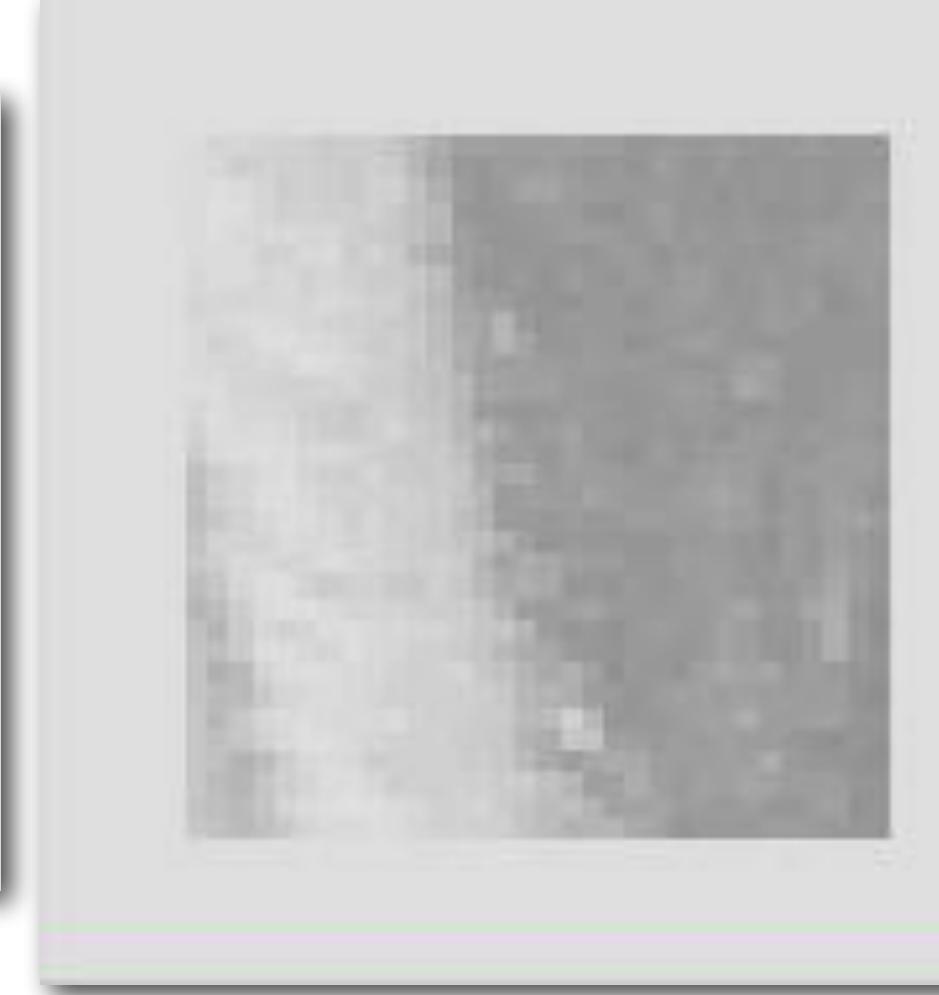
Black/White Digital Image: An Example



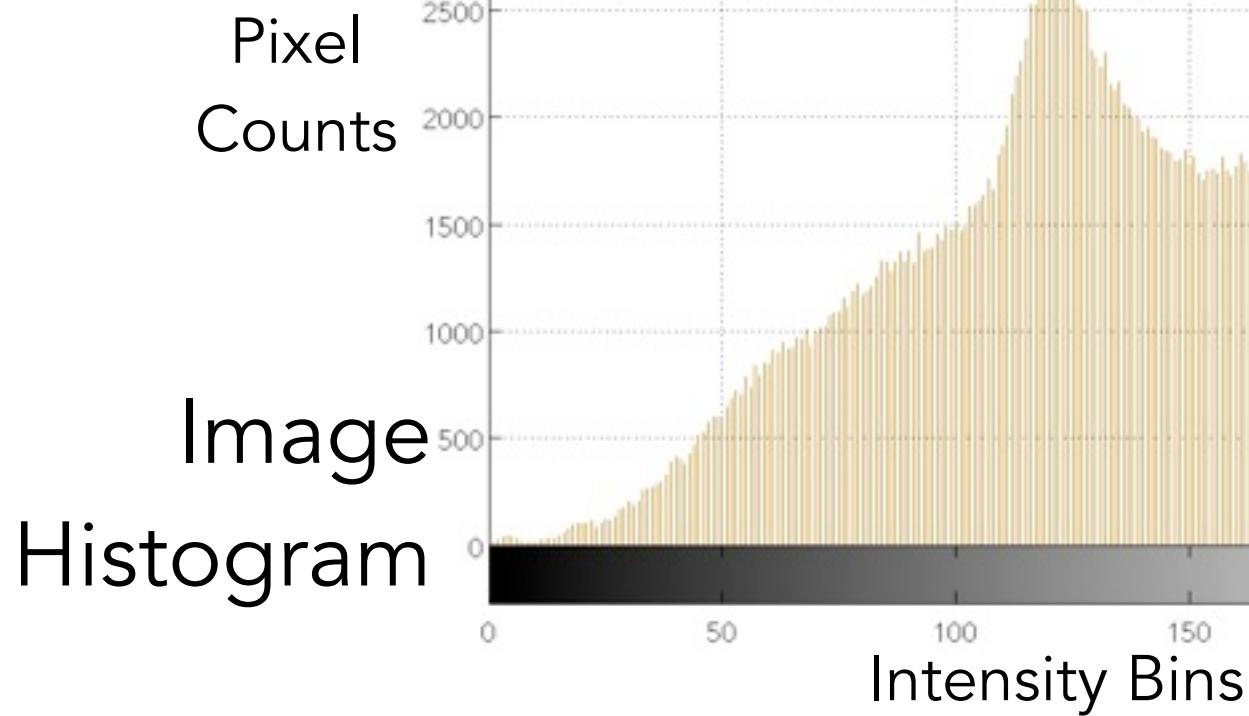
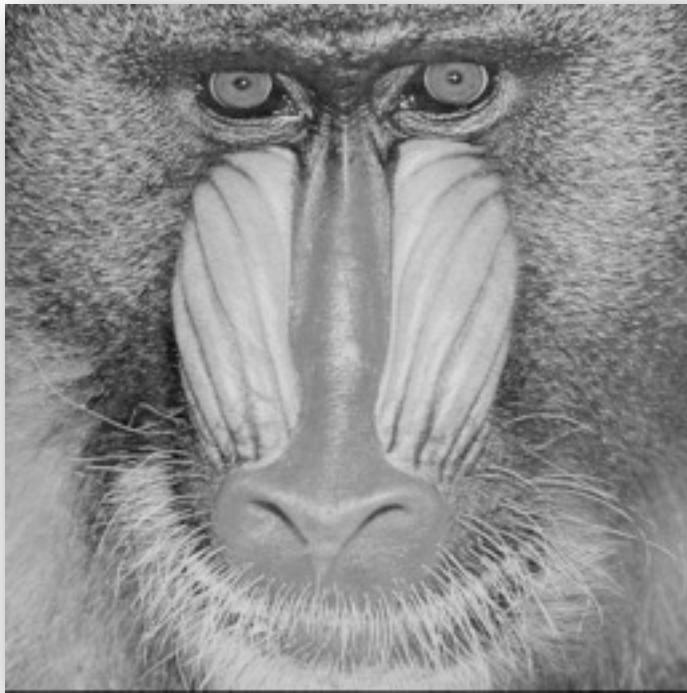
Image



Height Map

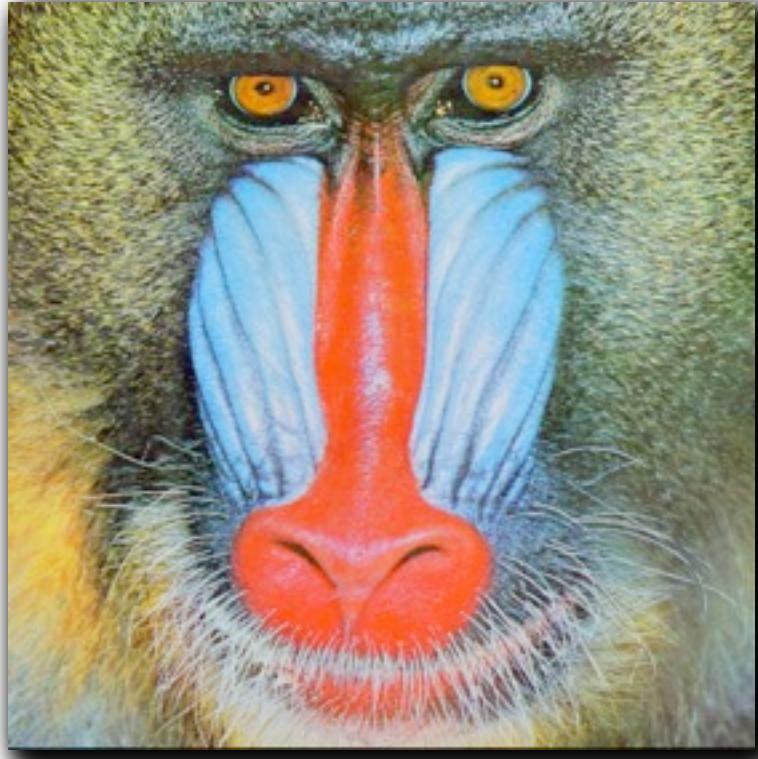


Digital Image Statistics



- ★ Once the discrete values for all pixels are known, we can undertake various statistical measures of the image (average, median, modes).
 - Scope of the entire image, and
 - Smaller windows, regions
- ★ Histogram shows the distribution of pixel intensities for the image
 - Can be separate for each channel, or region-based too.

Color Digital Image: An Example



Color

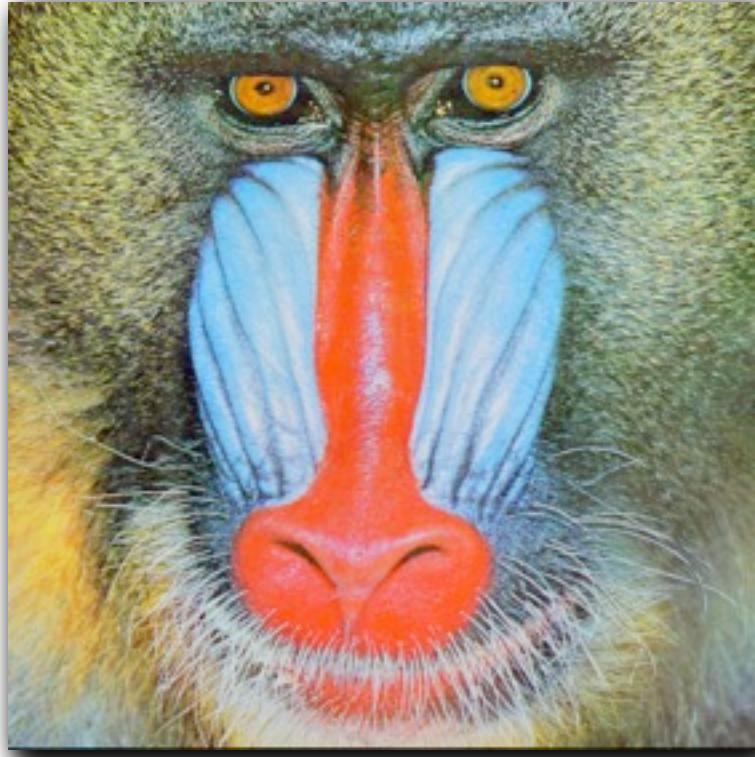
Red Channel

Green Channel

Blue Channel

- ★ A color image, is basically 3 color channels (with their own intensities) blended together
- ★ Makes 3D data structure of
 - Width x Height x Channels
- ★ Each pixel has therefore 3 intensities, in Red (R), Green (G), and Blue (B).

Color Digital Image: An Example



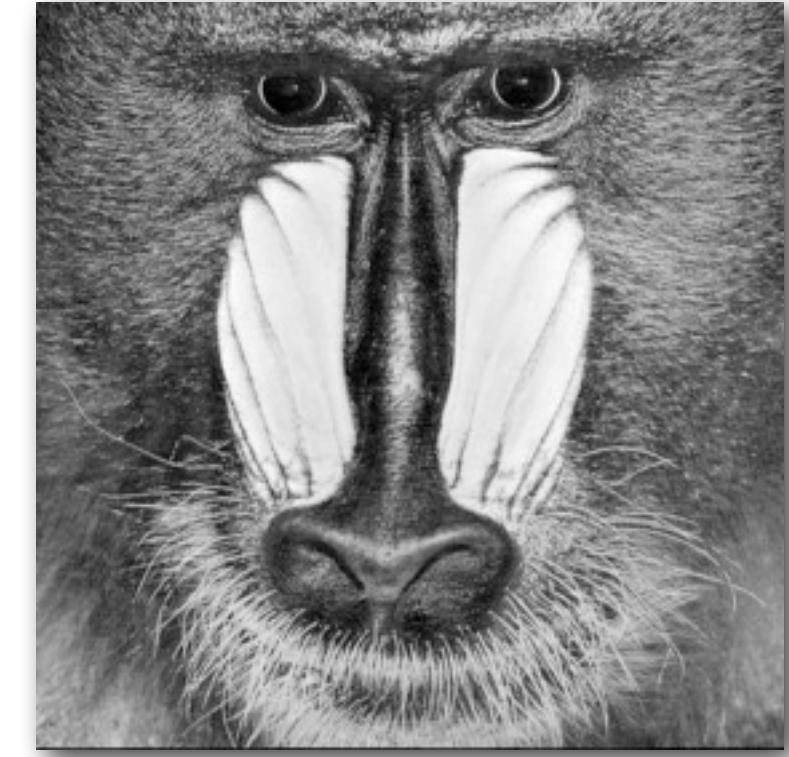
Color

Red Channel

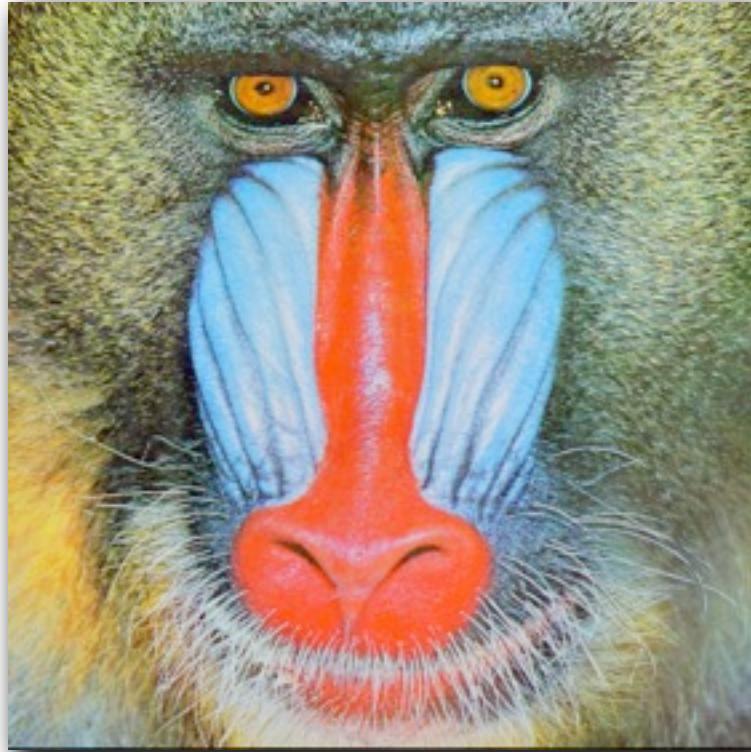
Green Channel

Blue Channel

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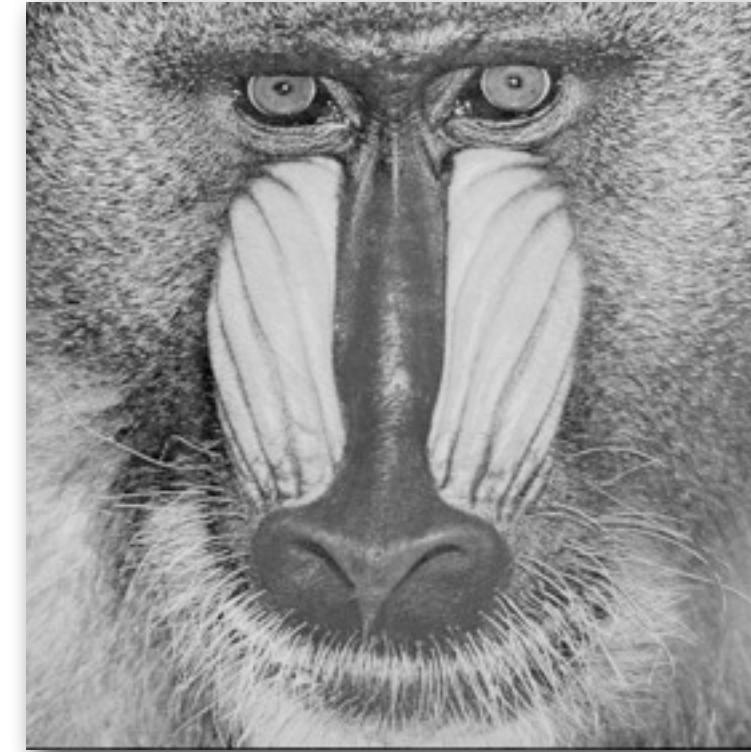


Color Digital Image: An Example

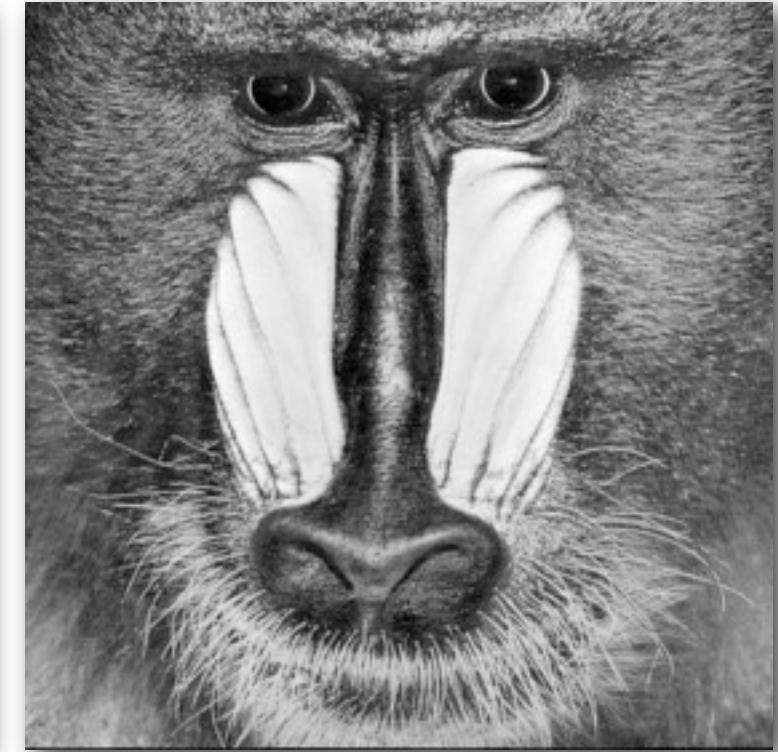


Color

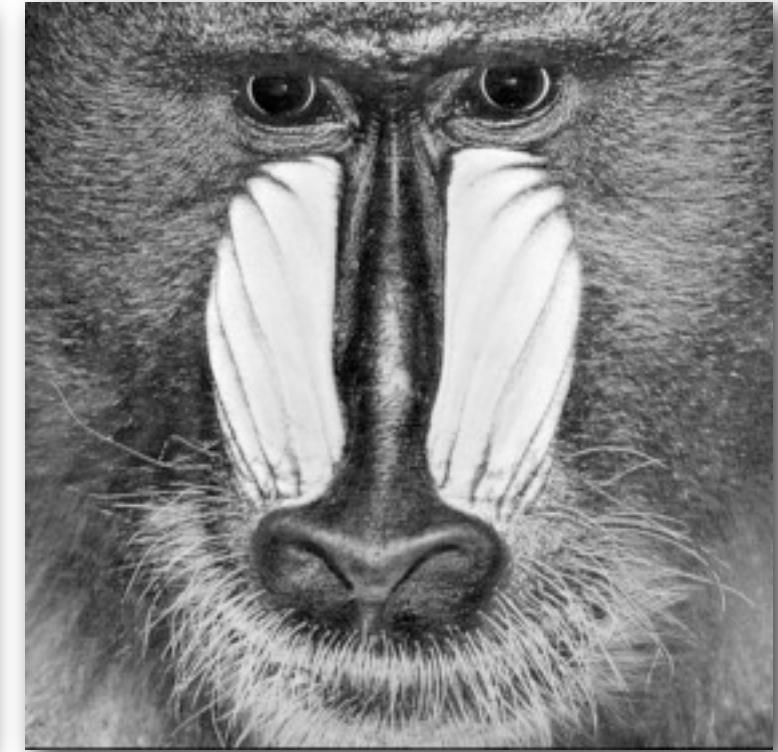
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Red Channel



Green Channel

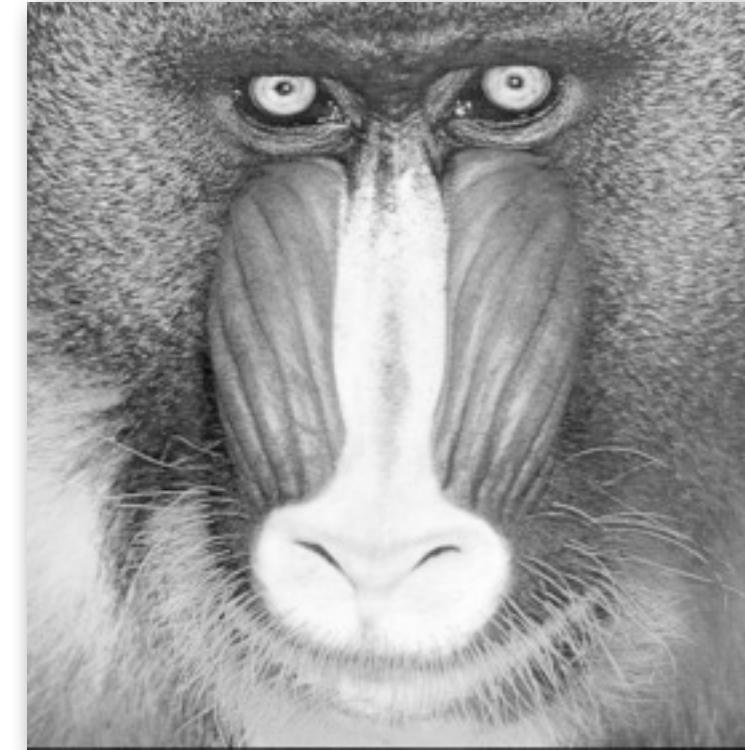


Blue Channel

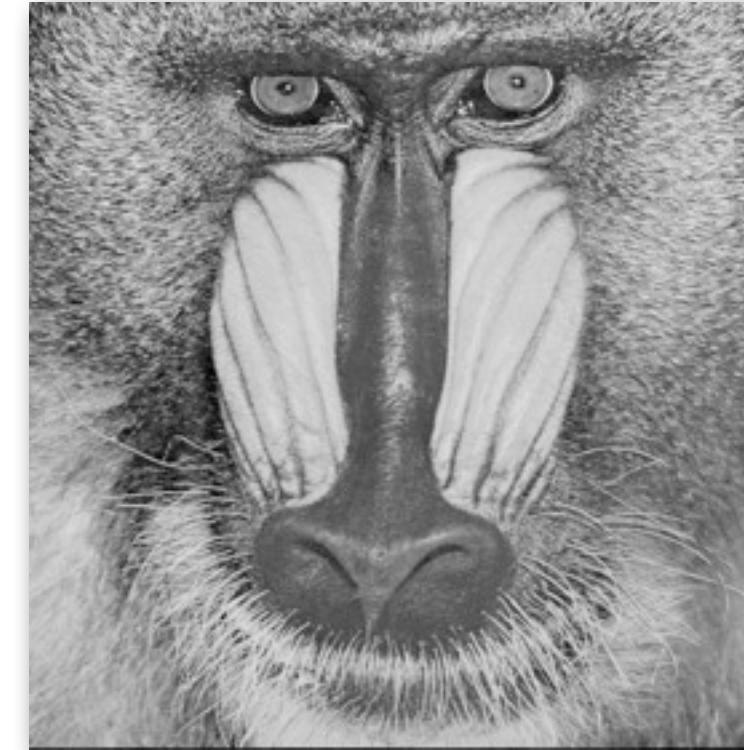
Color Digital Image: An Example



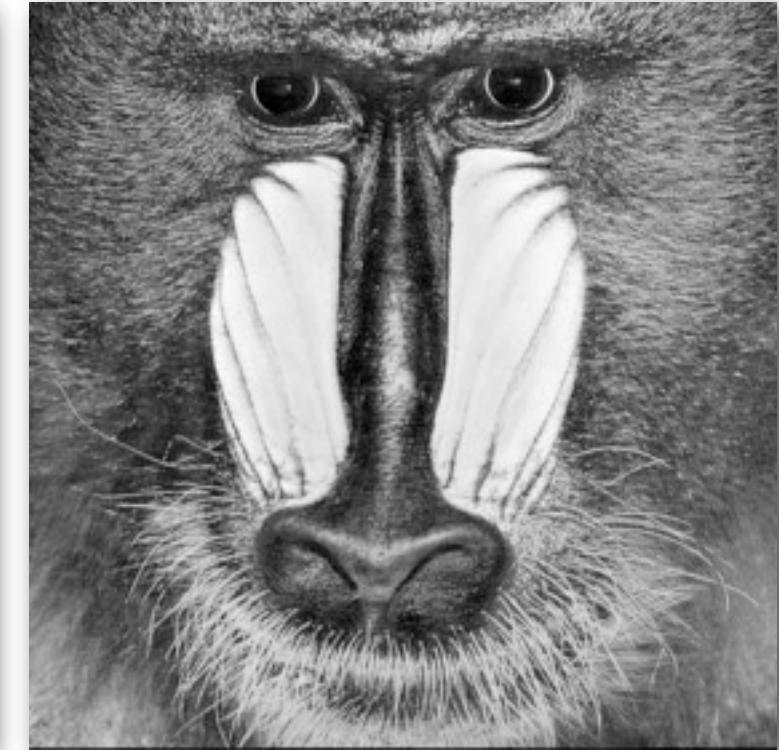
Color



Red Channel



Green Channel



Blue Channel

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Digital Image Formats

- ★ A Raster image format breaks the image into a series of colored dots called pixels.
- ★ The number of ones and zeros (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
- ★ Raster image formats can also be at 16, 24, and 32 bits-per-pixel
- ★ At the two highest levels, the pixels themselves can carry up to 16,777,216 different colors.
- ★ Common image formats are GIF, JPG, PPM, TIF, BMP, etc.
- ★ Will discuss Camera RAW format later.



Reading / Writing Images

★ In Python / with OpenCV

```
○ img = cv2.imread('filename.EXT');  
○ cv2.imwrite('filename.EXT', img);
```

★ Mostly need information

- dimensions of image, bits per pixel, order of color channels
- image compression information

★ Metadata about Pictures (Exchangeable Image File Format: EXIF, etc.)



Summary

- ★ Introduced the term Digital Image, and provided a context to show how it can be made into a computable object.
- ★ Showed different formats of images using examples of black/white and color images.
- ★ Introduced simple computational methods over images to compute image statistics.



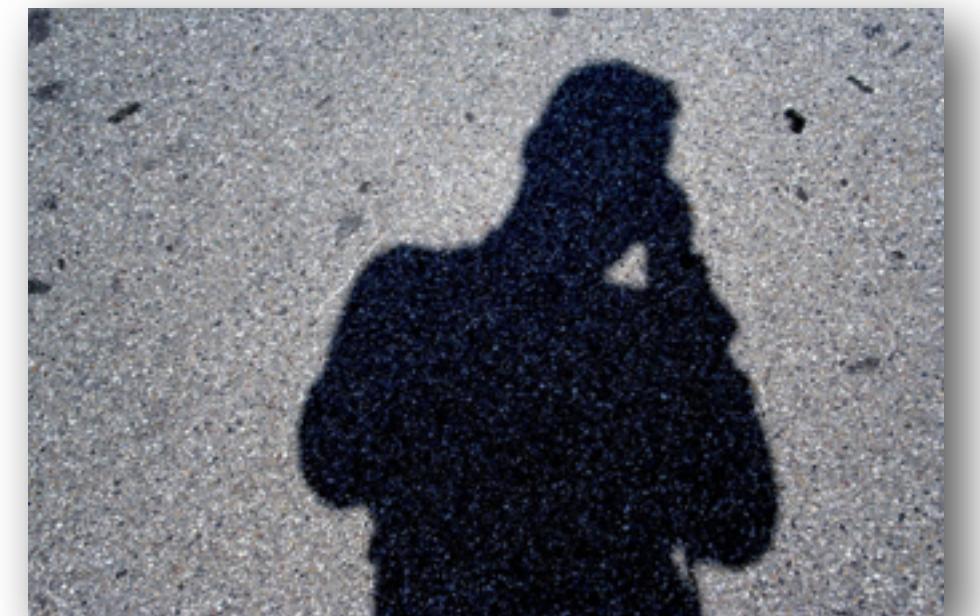
Next Class

★ 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](http://sipi.usc.edu/database/download.php?vol=misc&img=4.2.03)
- ★ Georgia Tech's Mascot Buzz image, courtesy Georgia Tech.
- ★ See the [Credits] on the Website for all Images Used



Computational Photography



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Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.