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# GENERAL IMS
# LECTURE 4 – PIXELS AND FILTERS

Prof. Dr. Francesco Maurelli
2018-09-14

## WHAT WE WILL LEARN TODAY?

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1. Image sampling and quantization
2. Image histograms
3. Images as functions
4. Linear systems (filters)
5. Convolution and correlation

Some background reading:
Forsyth and Ponce, Computer Vision, Chapter 7

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## Binary

# TYPES OF IMAGES

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## Binary

## Gray Scale

# TYPES OF IMAGES

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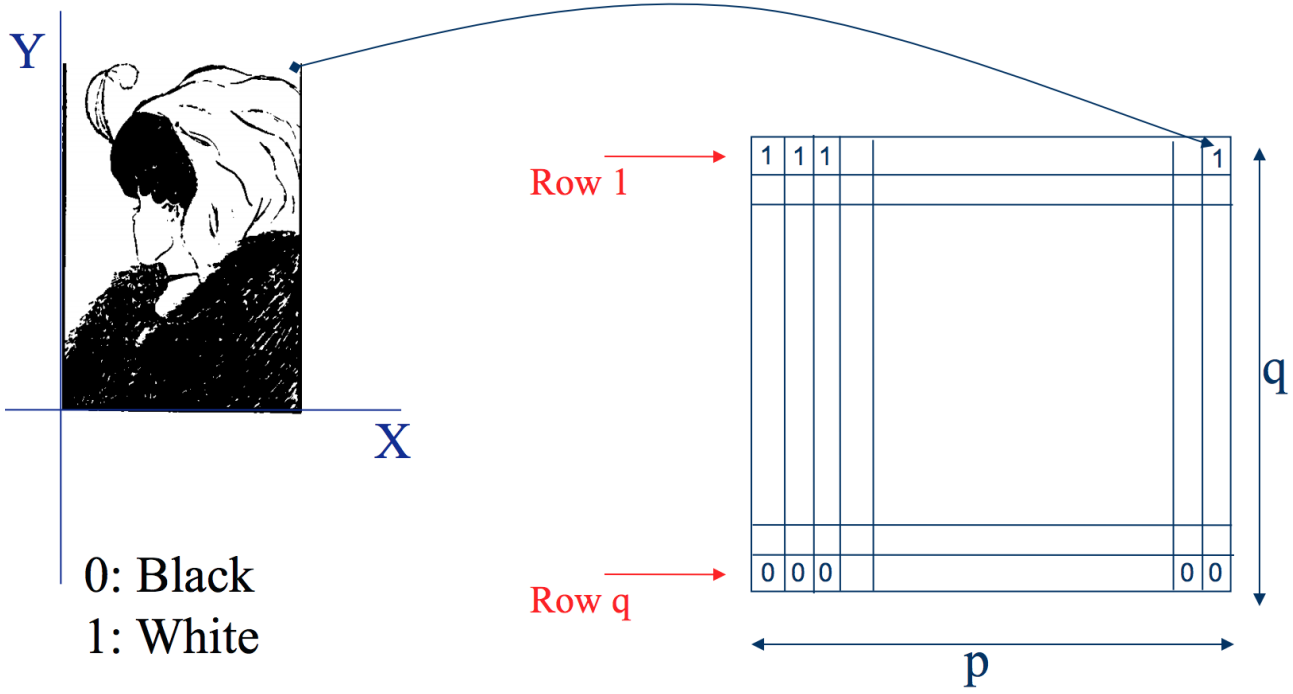
## Binary

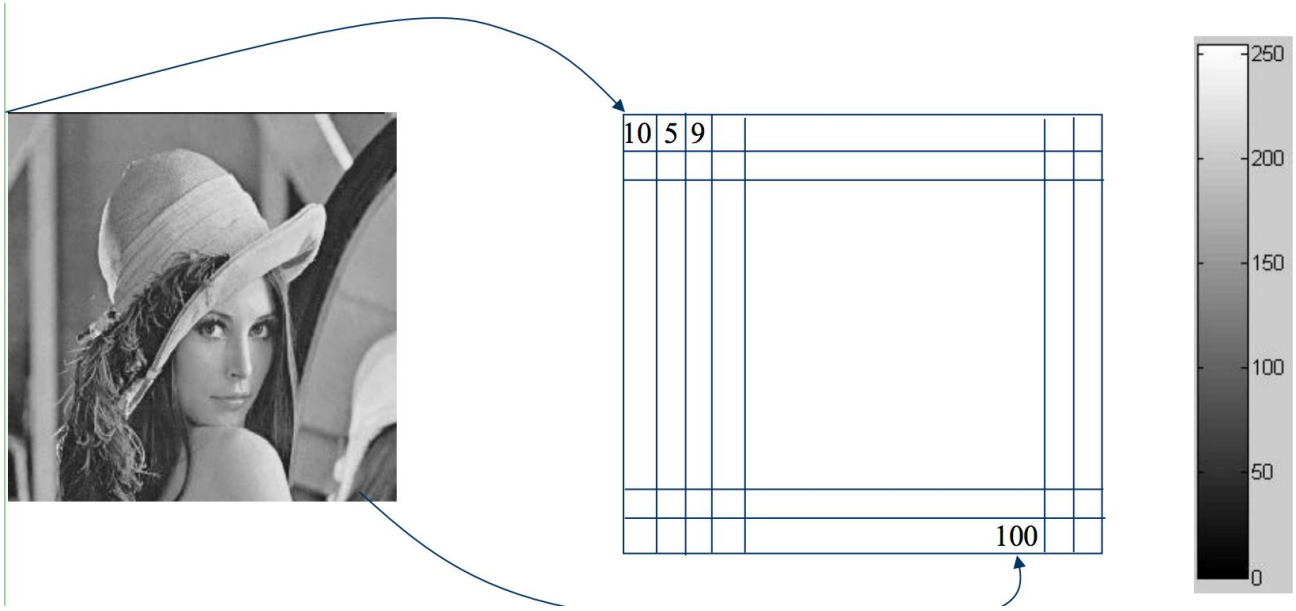
## Gray Scale

## Color

# BINARY IMAGE REPRESENTATION



# GRAYSCALE IMAGE REPRESENTATION

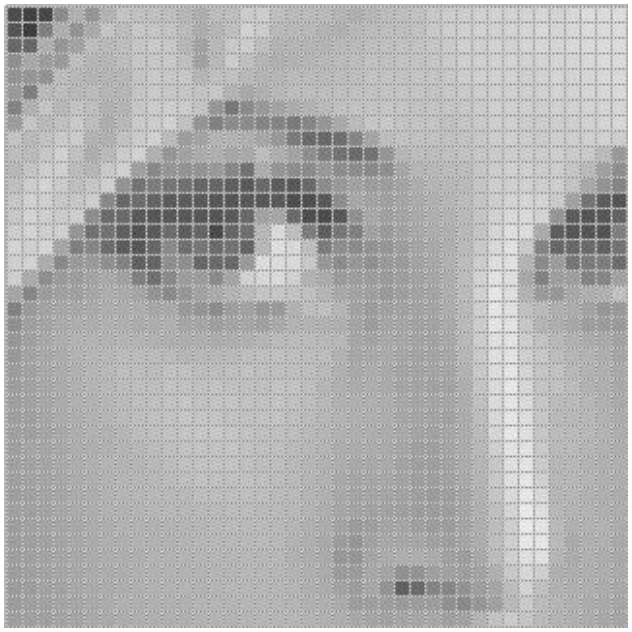


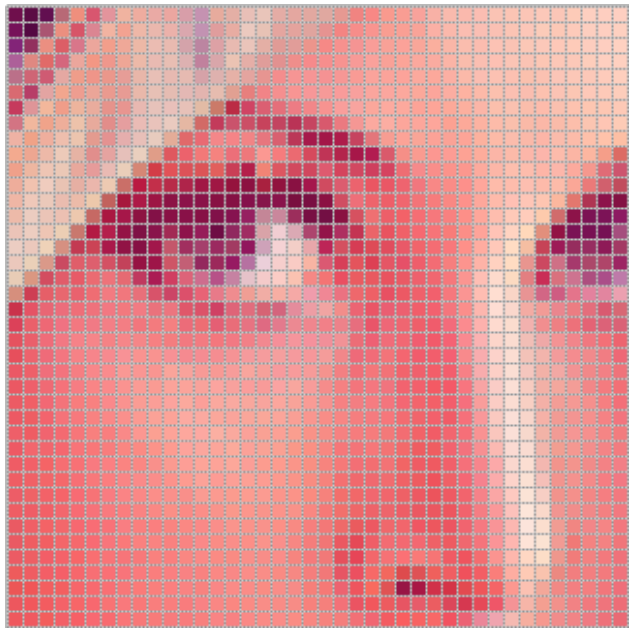
# COLOR IMAGE - ONE CHANNEL

# COLOR IMAGE REPRESENTATION

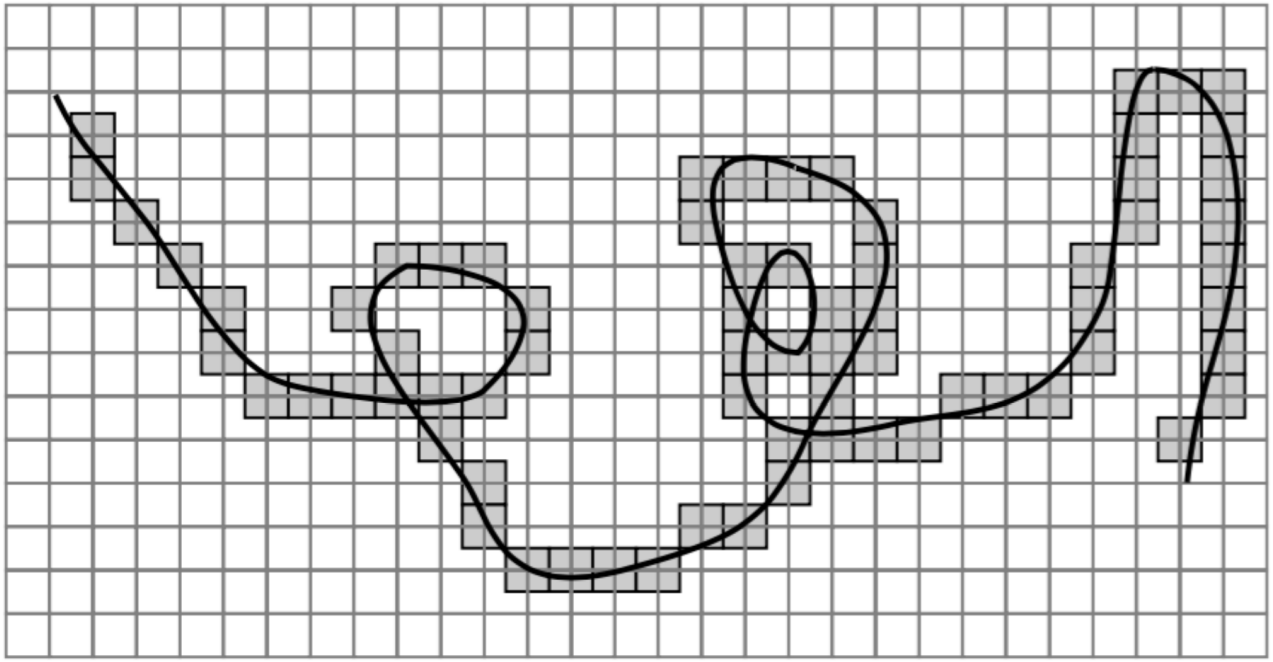
# IMAGES ARE SAMPLED

What happens when we zoom into the images we capture?





# ERRORS DUE SAMPLING



# RESOLUTION

is a **sampling** parameter, defined in dots per inch (DPI) or equivalent measures of spatial pixel density, and its standard value for recent screen technologies is 72 dpi

# IMAGES ARE SAMPLED AND QUANTIZED

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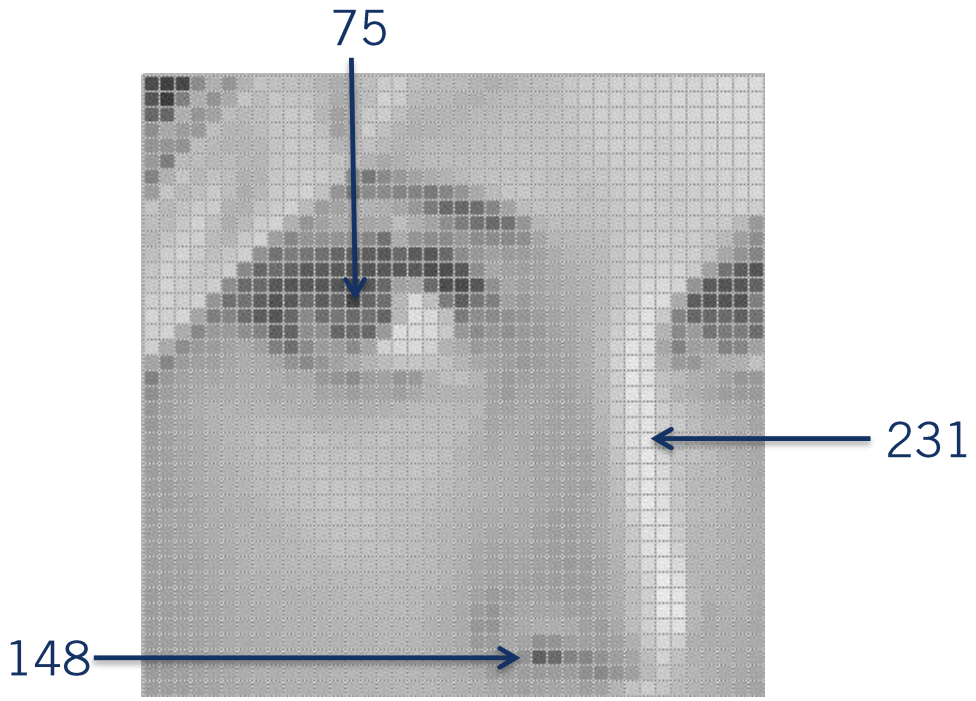
## 1. An image contains discrete number of pixels

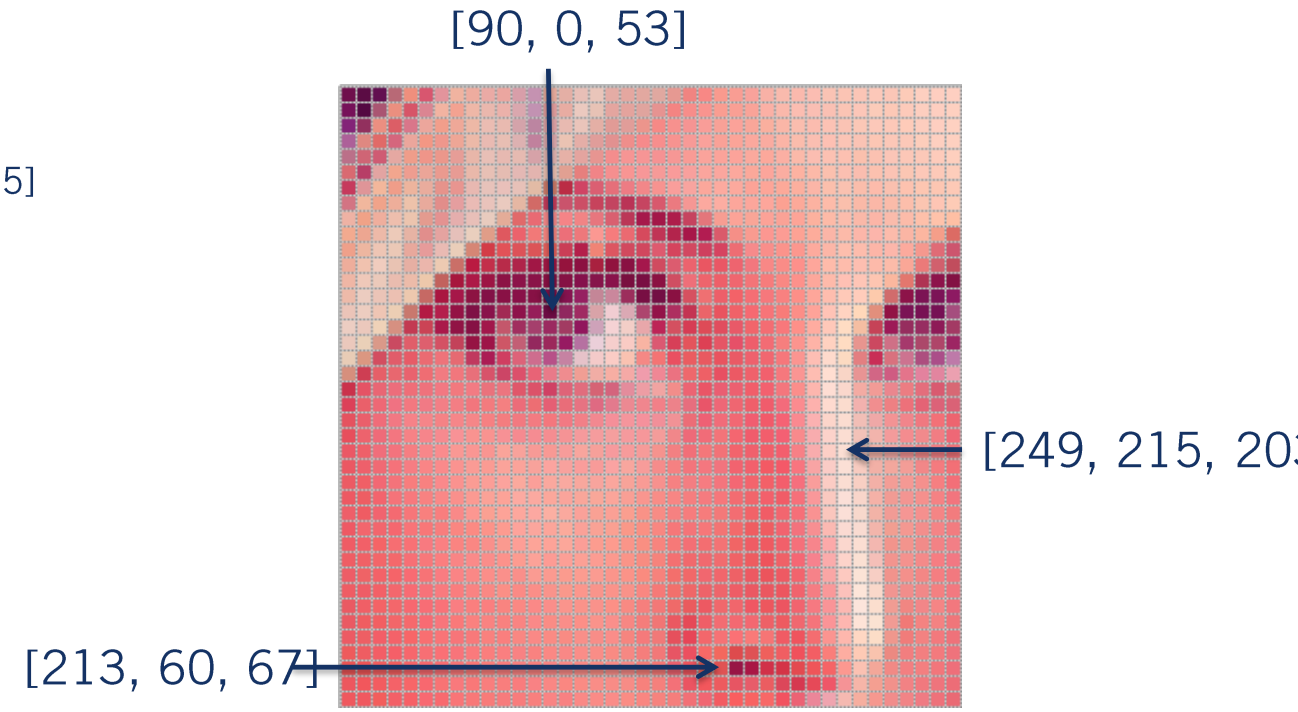
- A simple example
- Pixel value:
  - "grayscale"
    (or "intensity"): [0,255]



# IMAGES ARE SAMPLED AND QUANTIZED

1. An image contains discrete number of pixels

- A simple example
- Pixel value:
  - “grayscale” (or “intensity”): [0,255]
  - “color”
    - RGB: [R, G, B]
    - Lab: [L, a, b]
    - HSV: [H, S, V]



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# HISTOGRAM

1. Histogram of an image provides the frequency of the brightness (intensity) value in the image.

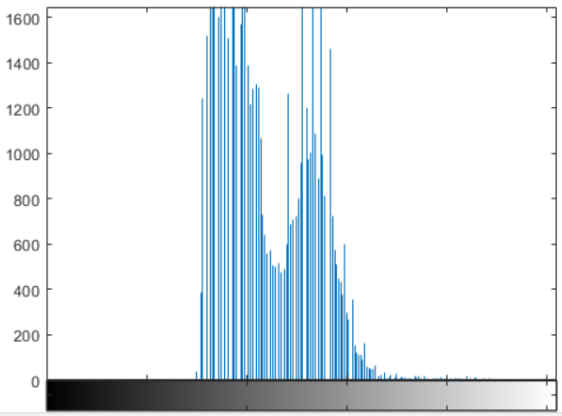
**Calculate Histogram**

Read a grayscale image into the workspace.

```
I = imread('pout.tif');
```

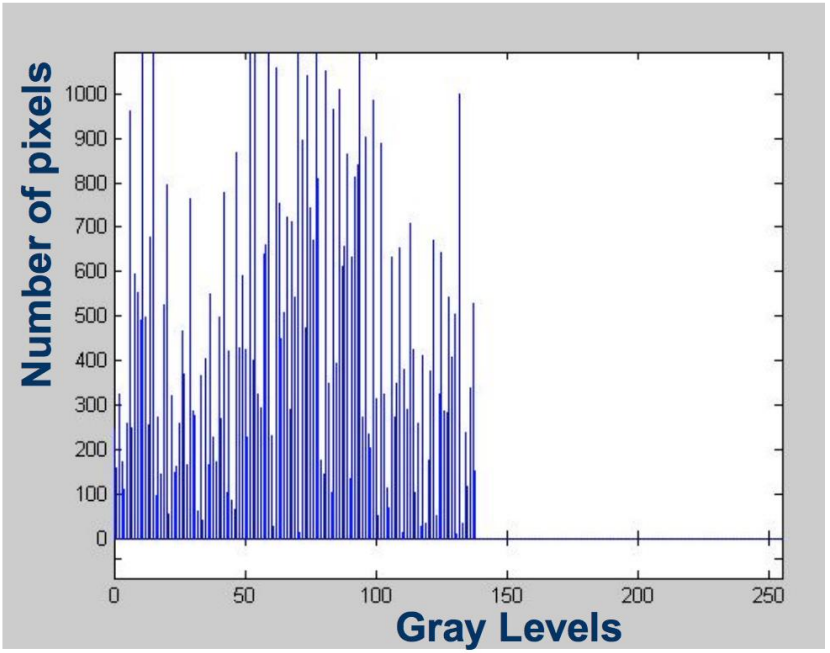
Display a histogram of the image. Since `I` is grayscale, by default the histogram will have 256 bins.

```
imhist(I)
```




# HISTOGRAM

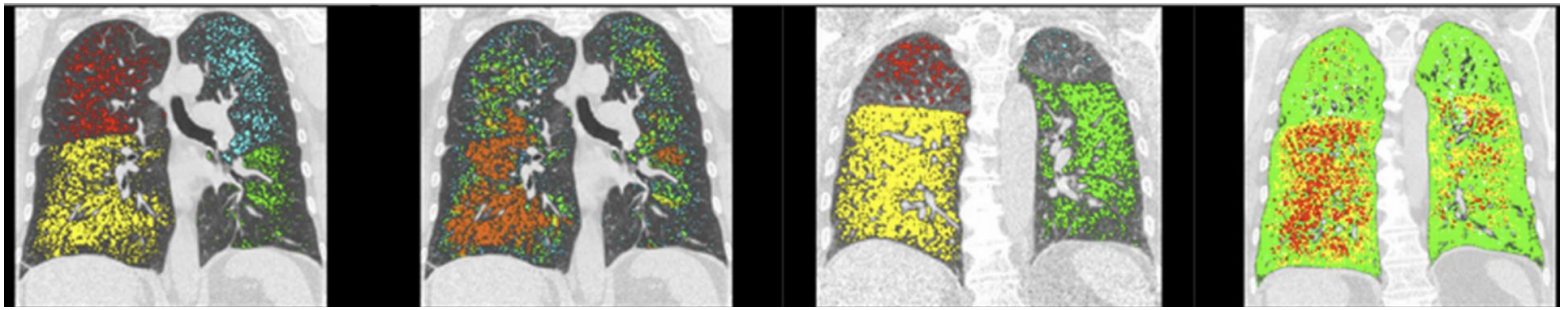
1. Histogram captures the distribution of gray levels in the image.
2. How frequently each gray level occurs in the image

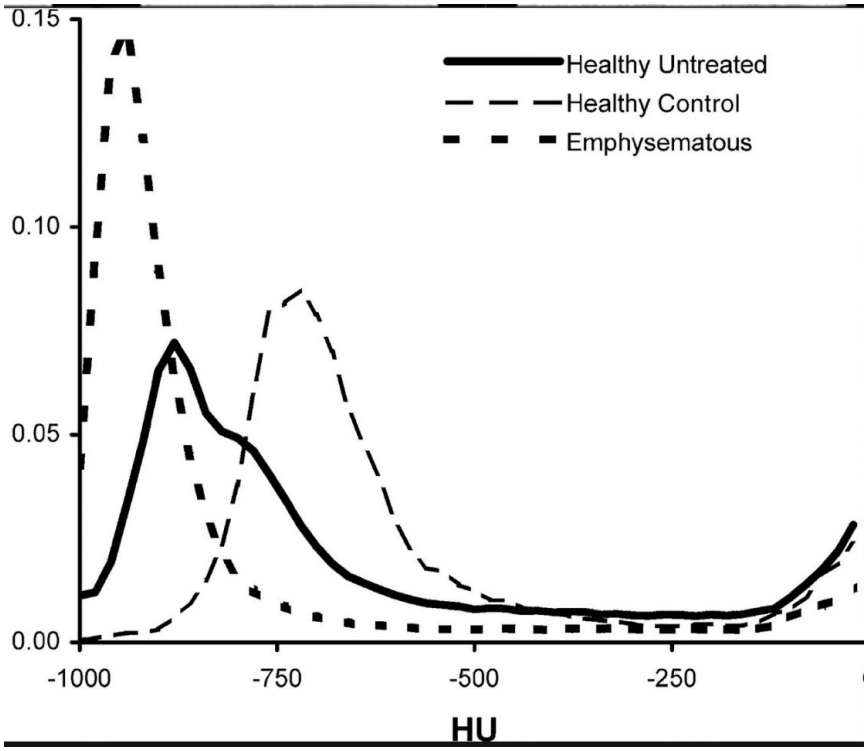


# HISTOGRAM


0
256
Count: 10192
Mean: 133.711
StdDev: 55.391
Min: 9
Max: 255
Mode: 178 (180)
0
256
Count: 10192
Mean: 104.637
StdDev: 89.862
Min: 11
Max: 254
Mode: 23 (440)

# HISTOGRAM – USE CASE





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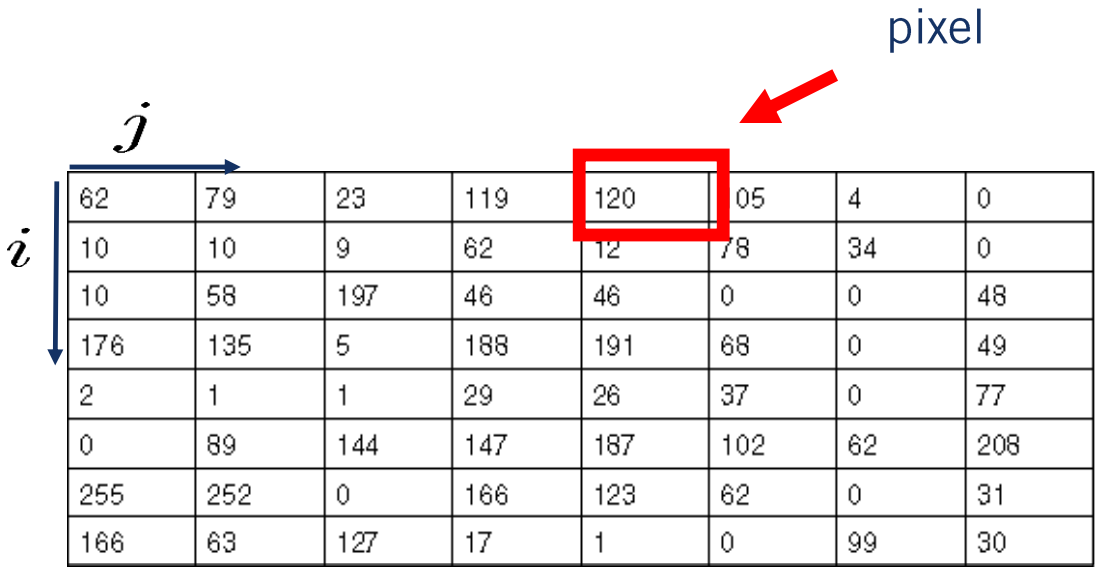
- Images are usually **digital** (**discrete**):
  - **Sample** the 2D space on a regular grid

- Represented as a matrix of integer values



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# Cartesian coordinates

$$f[n,m] = \begin{bmatrix} \ddots & & \vdots & & \\ & f[-1,-1] & f[0,-1] & f[1,-1] & \\ \dots & f[-1,0] & \underline{f[0,0]} & f[1,0] & \dots \\ & f[-1,1] & f[0,1] & f[1,1] & \\ & & \vdots & & \ddots \end{bmatrix}$$

Notation for discrete functions

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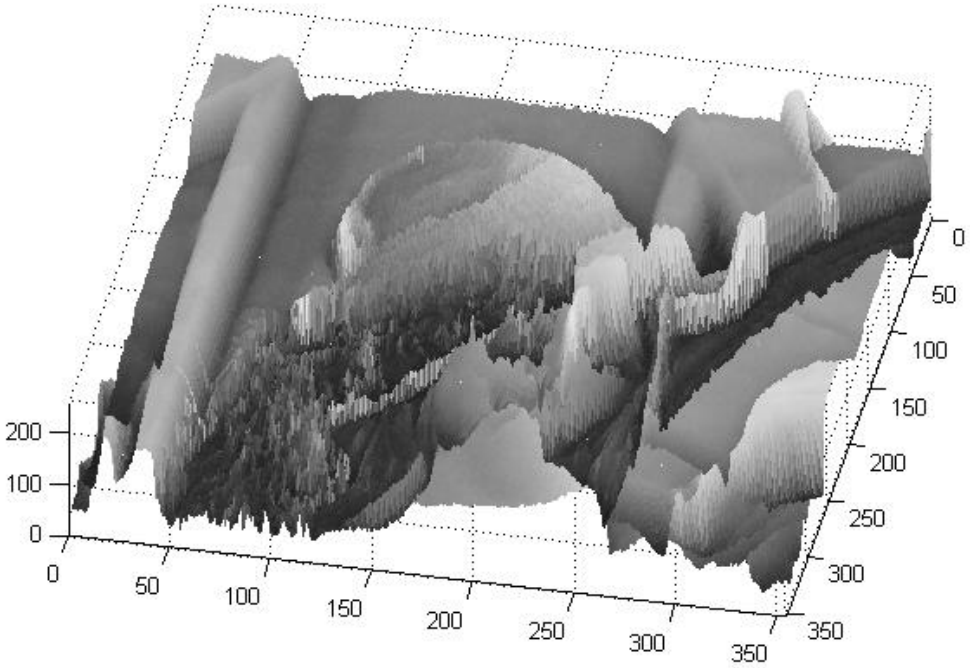
- **An Image** as a function *f* from $\mathbb{R}^2$ to $\mathbb{R}^M$:
  - $f(x, y)$ gives the **intensity** at position $(x, y)$
  - Defined over a rectangle, with a finite r



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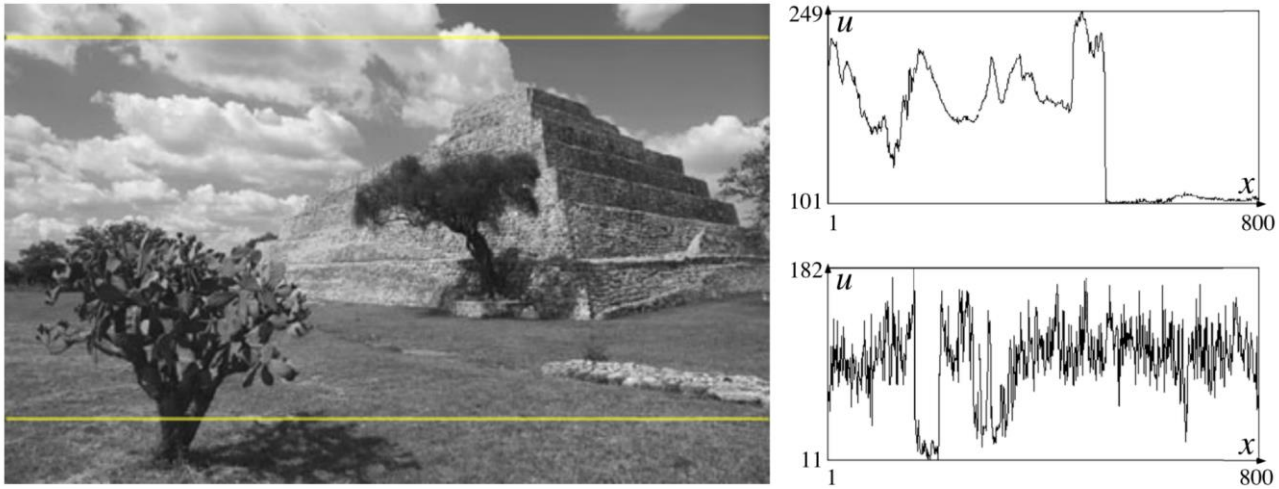
- **An Image** as a function $f$ from $\mathrm{R}^2$ to $\mathrm{R}^M$:
  - $f(x, y)$ gives the **intensity** at position $(x, y)$
  - Defined over a rectangle, with a finite range:

$$f: \underbrace{[a,b] \times [c,d]}_{\text{Domain support}} \rightarrow \underbrace{[0,255]}_{\text{range}}$$

- A color image: $$f(x,y) = \begin{bmatrix} r(x,y) \\ g(x,y) \\ b(x,y) \end{bmatrix}$$

# HISTOGRAMS ARE A TYPE OF IMAGE FUNCTION



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# Filtering:

– Forming a new image whose pixel values are transformed from original pixel values

## Goals:

- Goal is to extract useful information from images, or transform images into another domain where we can modify/enhance image properties
  - Features (edges, corners, blobs…)
  - super-resolution; in-painting; de-noising

1. we define a system as a unit that converts an input function f[n,m] into an output (or response) function g[n,m], where (n,m) are the independent variables.
   - In the case for images, (n,m) represents the **spatial position in the image.**

$$f[n,m] \rightarrow \boxed{\text{System } \mathcal{S}} \rightarrow g[n,m]$$

# DE-NOISING

Salt and pepper noise

## Super-resolution

## In-painting

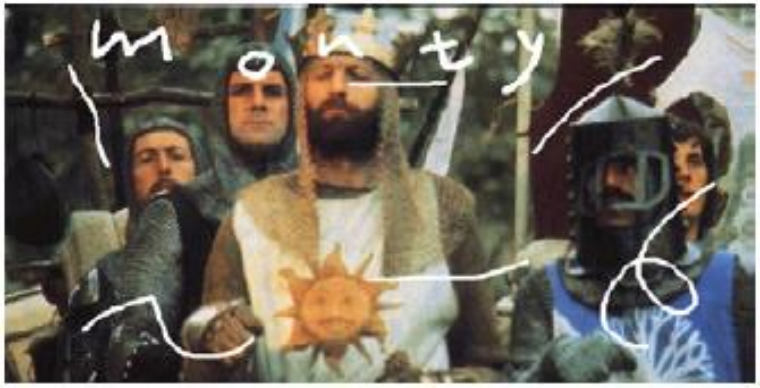


*Image Inpainting*, M. Bertalmío et al.
http://www.iua.upf.es/~mbertalmio//restoration.html

# ANY QUESTIONS?