VC 18/19 – TP3
Digital Images

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos
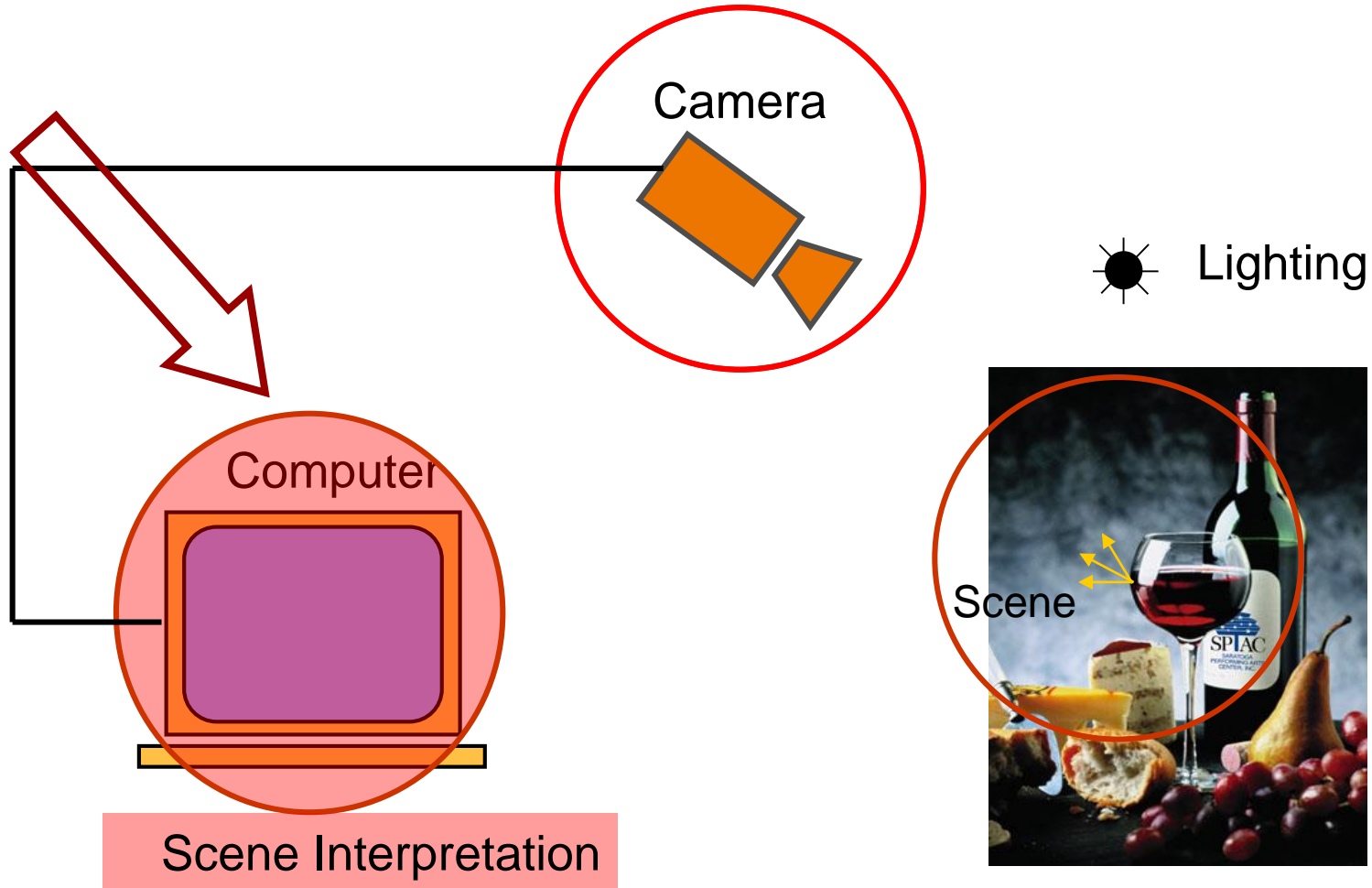
Miguel Tavares Coimbra

Outline

- Sampling and quantization
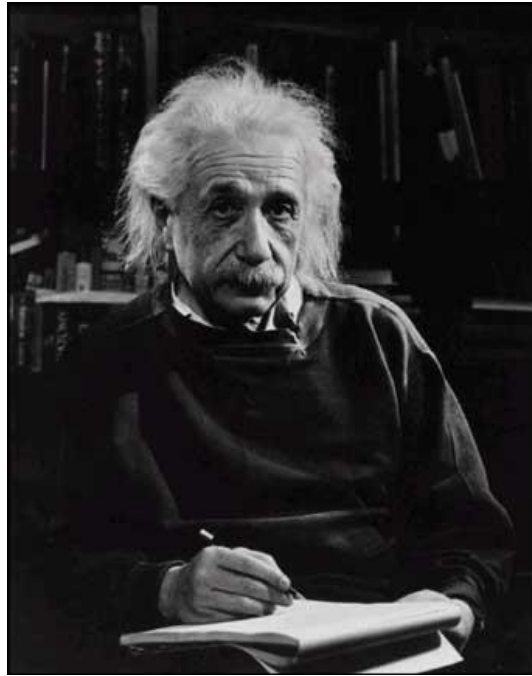- Data structures for digital images
- Histograms

Topic: Sampling and quantization

- **Sampling and quantization**
- Data structures for digital images
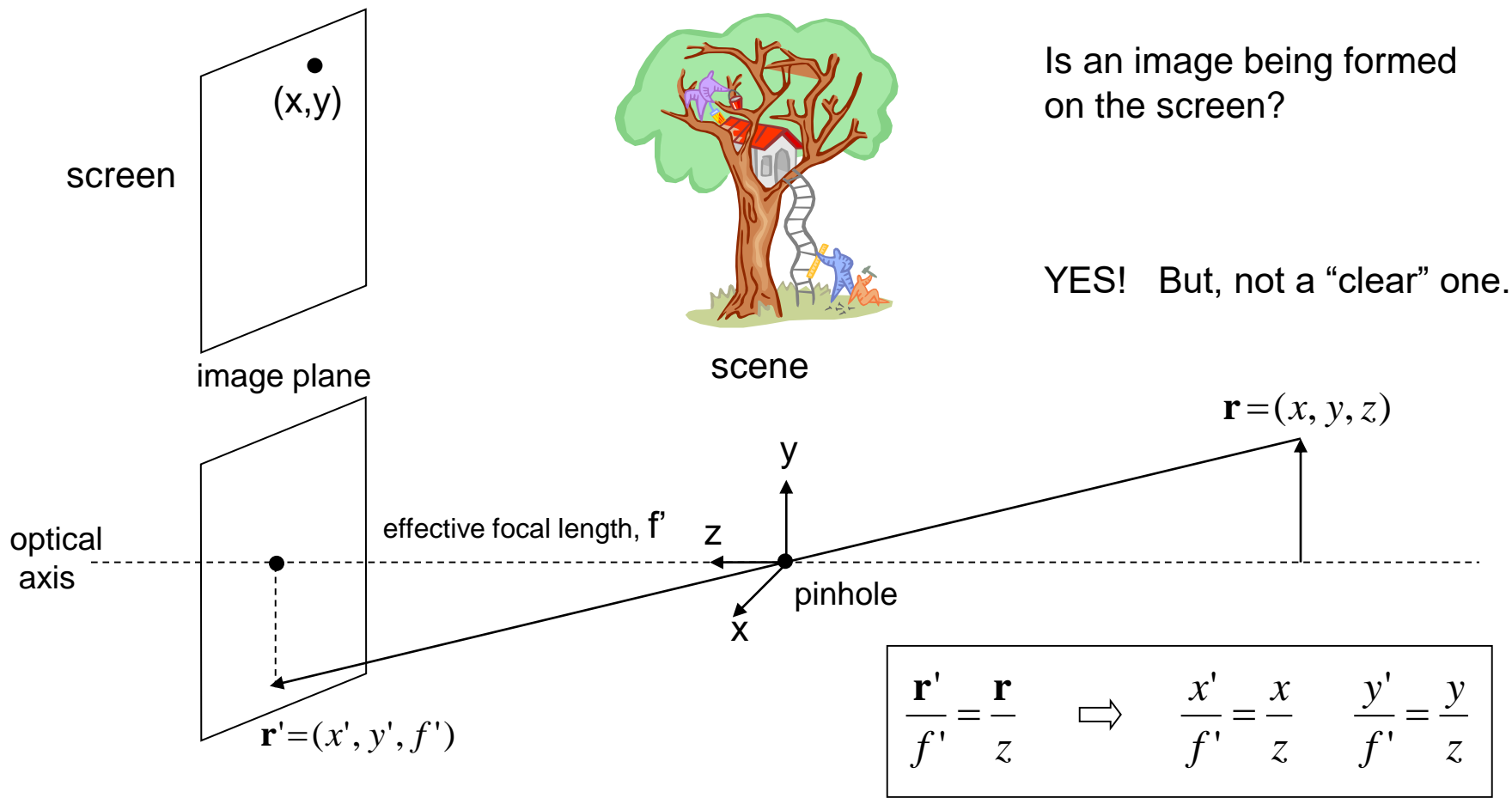- Histograms

Components of a Computer Vision System

Camera

Lighting

Computer

Scene

Scene Interpretation

Digital Images

What we see

What a computer sees

Pinhole and the Perspective Projection

(x,y)

screen

image plane

scene

Is an image being formed on the screen?

YES!   But, not a "clear" one.

$\mathbf{r} = (x, y, z)$

y

z

effective focal length, $\mathbf{f'}$

optical axis

pinhole

x

$\mathbf{r'} = (x', y', f')$

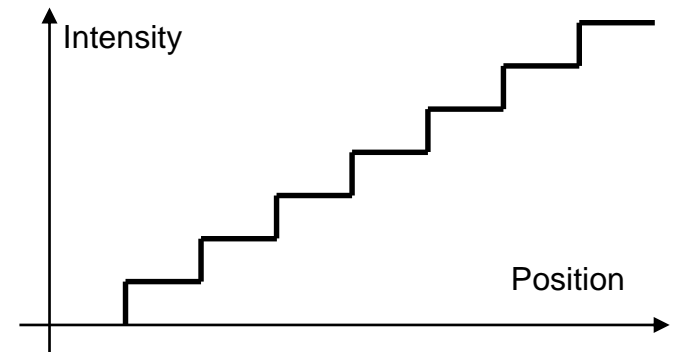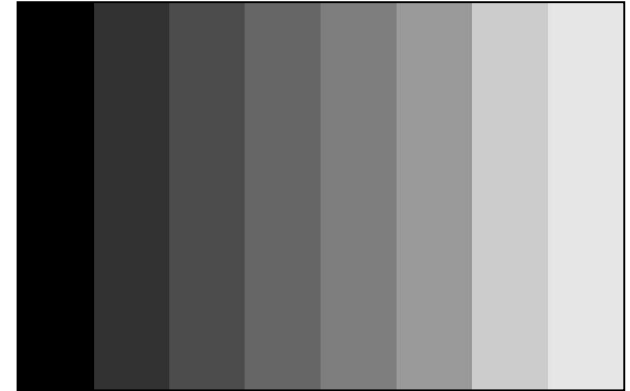$$\frac{\mathbf{r'}}{f'} = \frac{\mathbf{r}}{z} \quad \Rightarrow \quad \frac{x'}{f'} = \frac{x}{z} \quad \frac{y'}{f'} = \frac{y}{z}$$

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Simple Image Model

- Image as a 2D light-intensity function

$$f(x, y)$$

- Continuous

- Non-zero, finite value

$$0 < f(x, y) < \infty$$
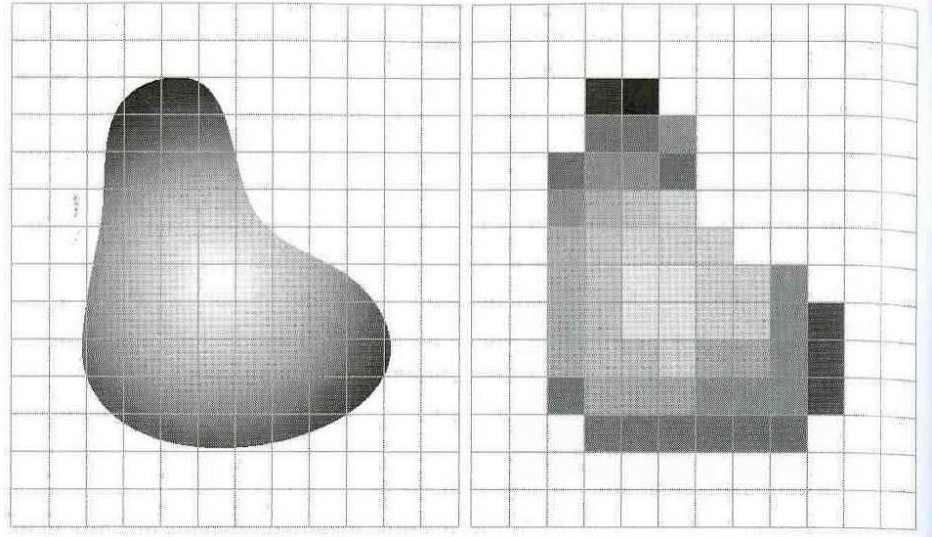

Intensity

Position

[Gonzalez & Woods]

Analog to Digital

The scene is:

- **projected** on a 2D plane,

- **sampled** on a regular grid, and each sample is
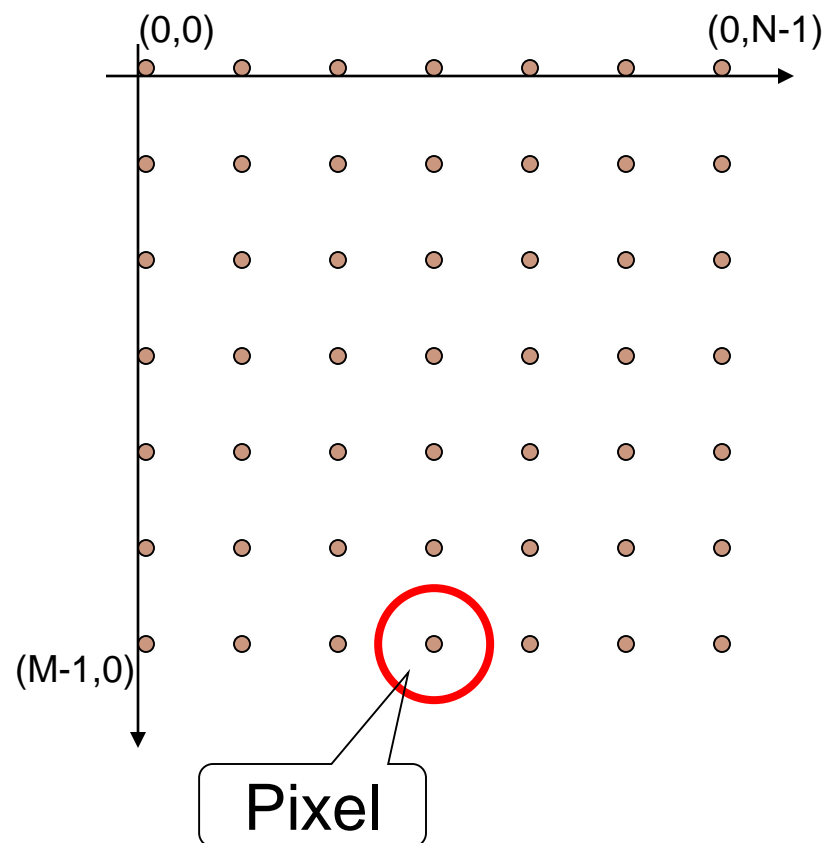
- **quantized** (rounded to the nearest integer)

$$f(i, j) = \text{Quantize}\{f(i\Delta, j\Delta)\}$$
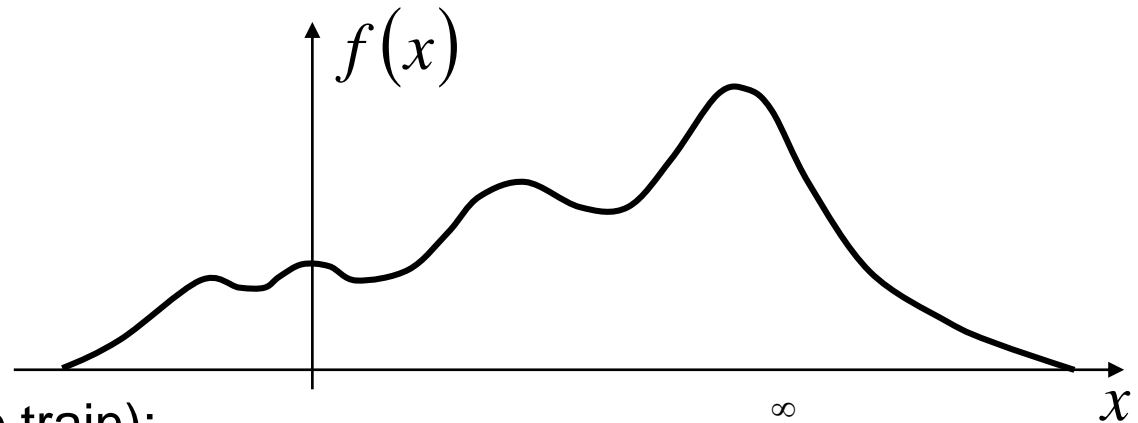
Images as Matrices

- Each point is a pixel with amplitude:
  - f(x,y)

- An image is a matrix with size N x M

M =   [(0,0) (0,1) …
      [(1,0) (1,1) …

      …

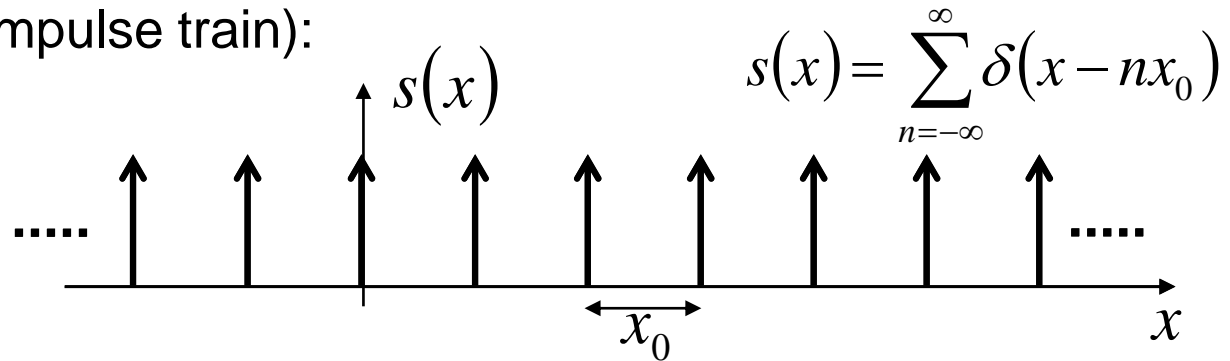(0,0)   (0,N-1)

(M-1,0)

Pixel

Sampling Theorem

Continuous signal:

$$f(x)$$

Shah function (Impulse train):

$$s(x) = \sum_{n=-\infty}^{\infty} \delta(x - nx_0)$$

$$s(x)$$

$$x_0$$

Sampled function:

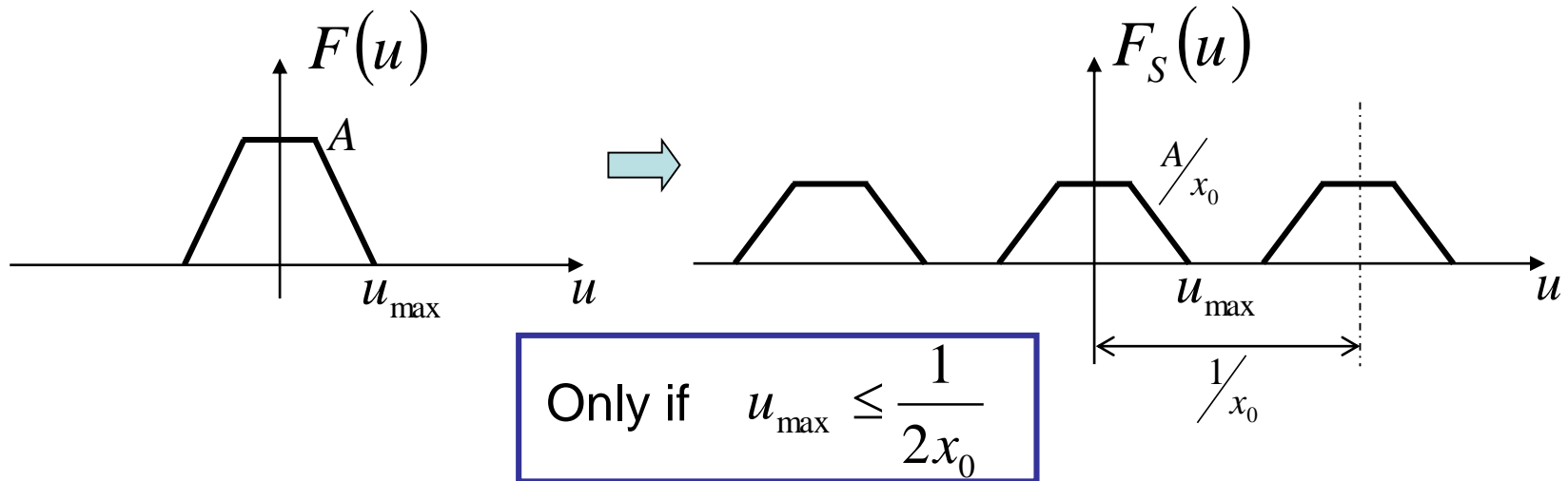$$f_s(x) = f(x)s(x) = f(x)\sum_{n=-\infty}^{\infty} \delta(x - nx_0)$$

Sampling Theorem

Sampled function:

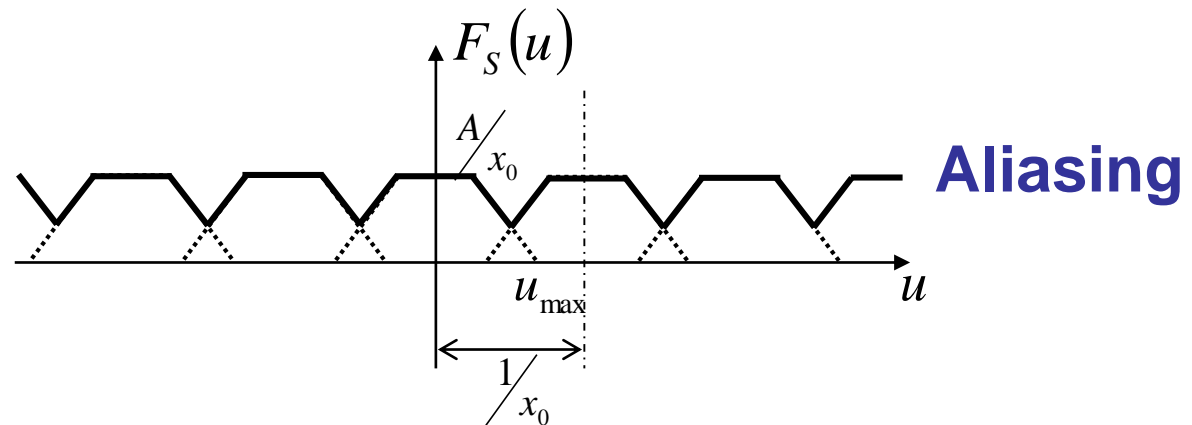$$f_s(x) = f(x)s(x) = f(x)\sum_{n=-\infty}^{\infty}\delta(x-nx_0)$$

Sampling frequency $\dfrac{1}{x_0}$

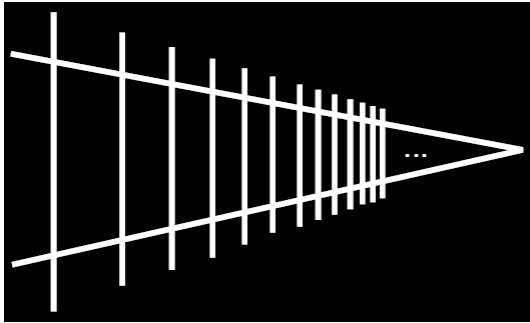$$F_S(u) = F(u) * S(u) = F(u) * \frac{1}{x_0}\sum_{n=-\infty}^{\infty}\delta\left(u - \frac{n}{x_0}\right)$$

Only if $u_{max} \leq \dfrac{1}{2x_0}$

Nyquist Theorem

If $\quad u_{max} > \dfrac{1}{2x_0}$

Aliasing

$F_S(u)$

$\dfrac{A}{x_0}$

u_{max}

u

$\dfrac{1}{x_0}$
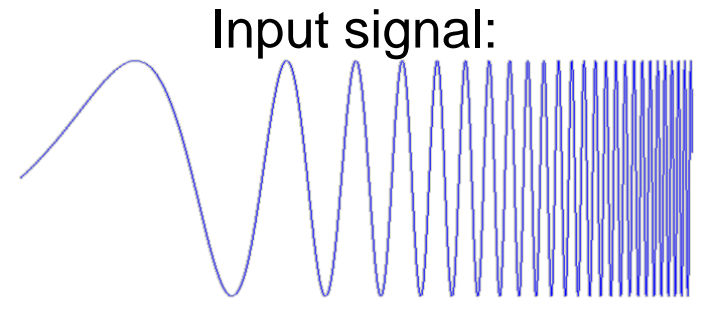
Sampling frequency must be greater than $2u_{max}$
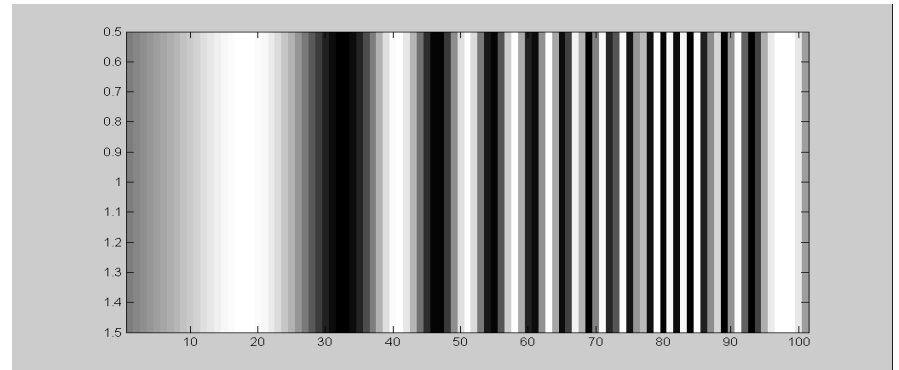
Aliasing

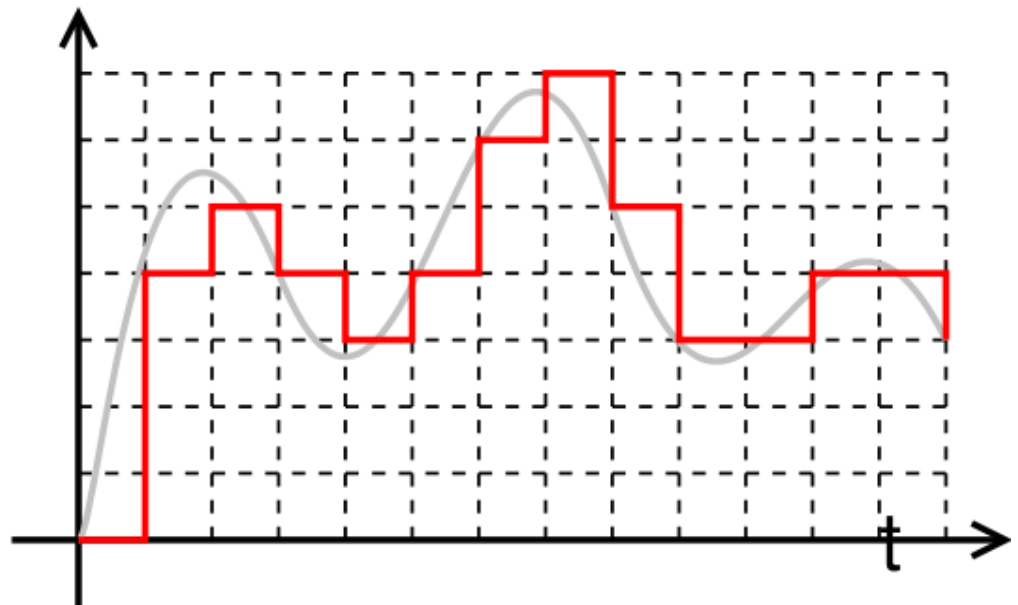Picket fence receding into the distance will produce aliasing…

WHY?

Input signal:

Matlab output:

x = 0:.05:5; imagesc(sin((2.^x).*x))
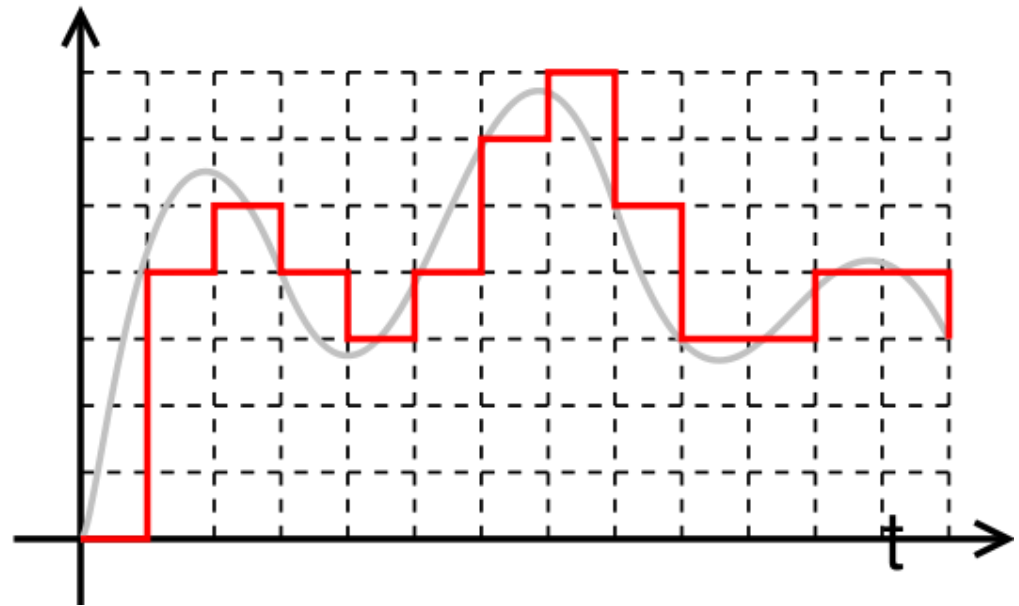
Quantization

- Analog: $0 < f(x, y) < \infty$

- Digital: Infinite storage space per pixel!

- Quantization

Quantization Levels

- G - number of levels
- m – storage bits
- Round each value to its nearest level

$$G = 2^m$$

Effect of quantization

Effect of quantization

Image Size

- ## Storage space

  - Spatial resolution: N x M
  - Quantization: m bits per pixel
  - Required bits b:
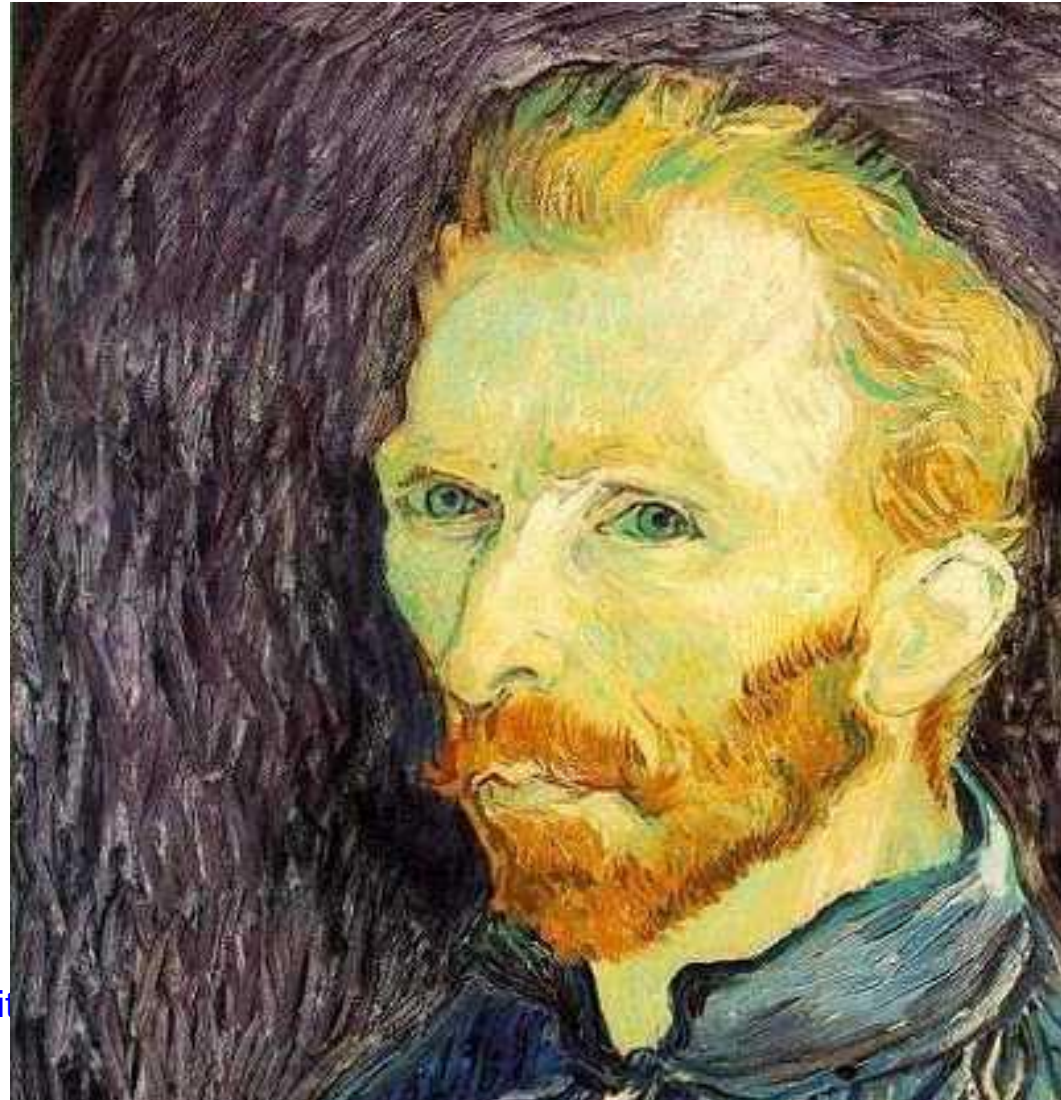
$$b = N \times M \times m$$

- ## Rule of thumb:

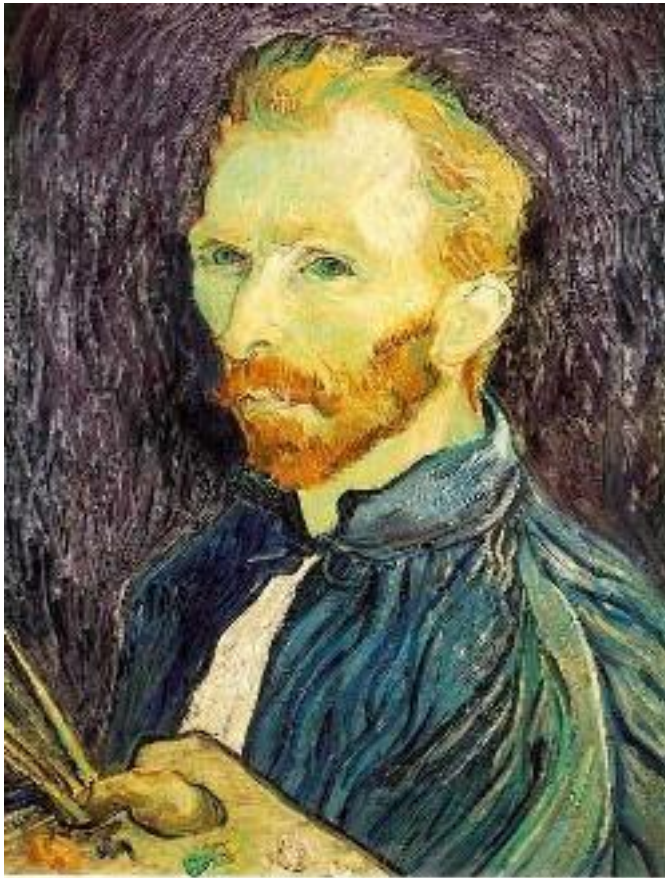 - More storage space means more image quality

Image Scaling

This image is too big to fit on the screen. How can we reduce it?

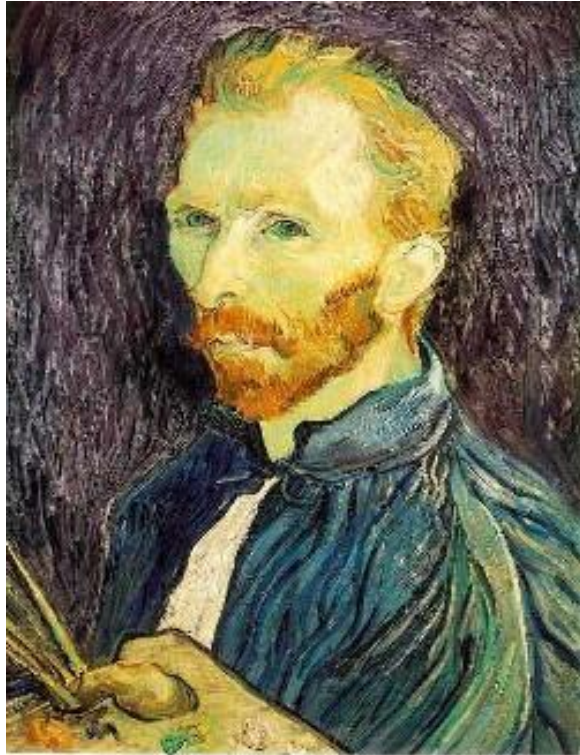How to generate a half-sized version?

Sub-sampling

1/8

1/4

Throw away every other row and column to create a 1/2 size image - called *image sub-sampling*

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Sub-sampling

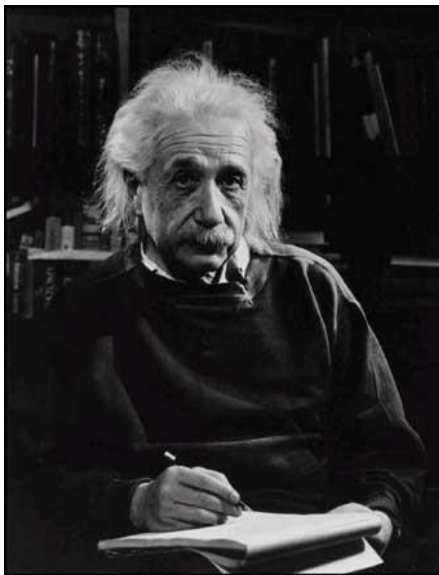
1/2   1/4 (2x zoom)   1/8 (4x zoom)

Topic: Data structures for digital images

- Sampling and quantization
- Data structures for digital images
- Histograms

Data Structures for Digital Images
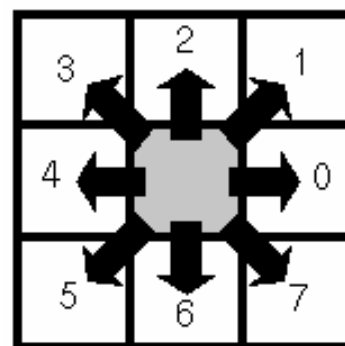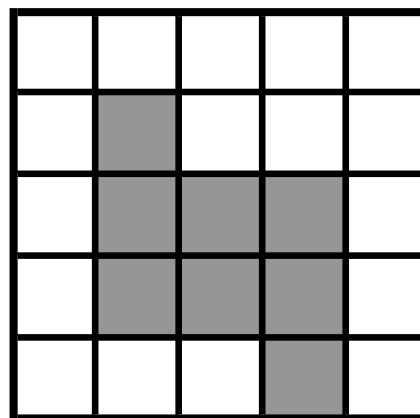
- Are there other ways to represent digital images?

What we see   What a computer sees

Chain codes

- Chains represent the borders of objects.

- Coding with *chain codes*.
  - Relative.
  - Assume an initial starting point for each object.
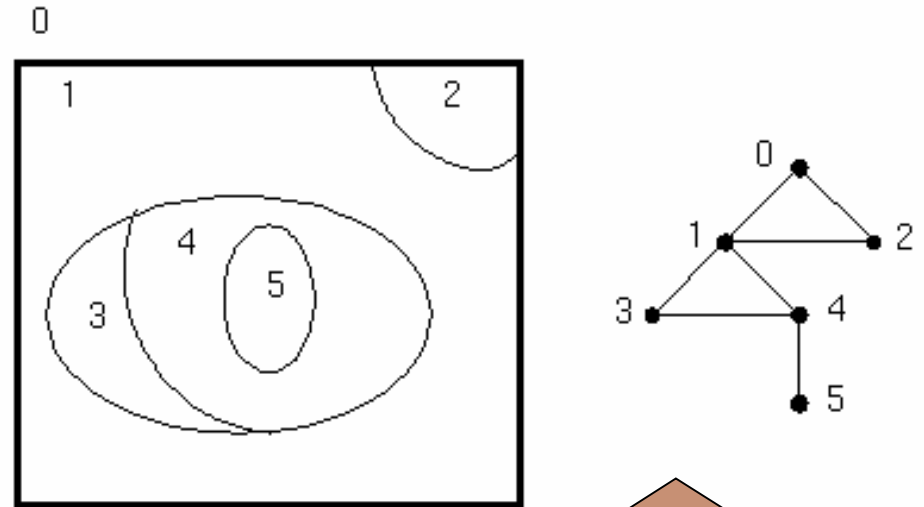
- Needs segmentation!

Freeman Chain Code

Using a Freeman Chain Code and considering the top-left pixel as the starting point:
70663422

Topological Data Structures

- *Region Adjacency Graph*
  - **Nodes** - Regions
  - **Arcs** – Relationships
- Describes the elements of an image and their spatial relationships.
- Needs segmentation!

Region Adjacency Graph

Relational Structures

- Stores relations between objects.

- Important semantic information of an image.

- Needs segmentation and an image description (features)!
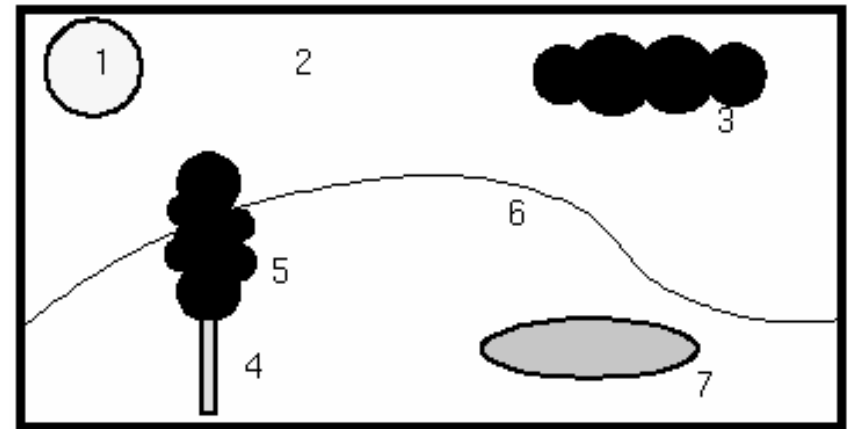
No.	Object name	Colour	Min. row	Min. col.	Inside
1	sun	white	5	40	2
2	sky	blue	0	0	-
3	cloud	grey	20	180	2
4	tree trunk	brown	95	75	6
5	tree crown	green	53	63	-
6	hill	light green	97	0	-
7	pond	blue	100	160	6

Relational Table

Topic: Histograms

- Sampling and quantization
- Data structures for digital images
- Histograms

Histograms

- "In statistics, a histogram is a graphical display of tabulated frequencies."

  [Wikipedia]

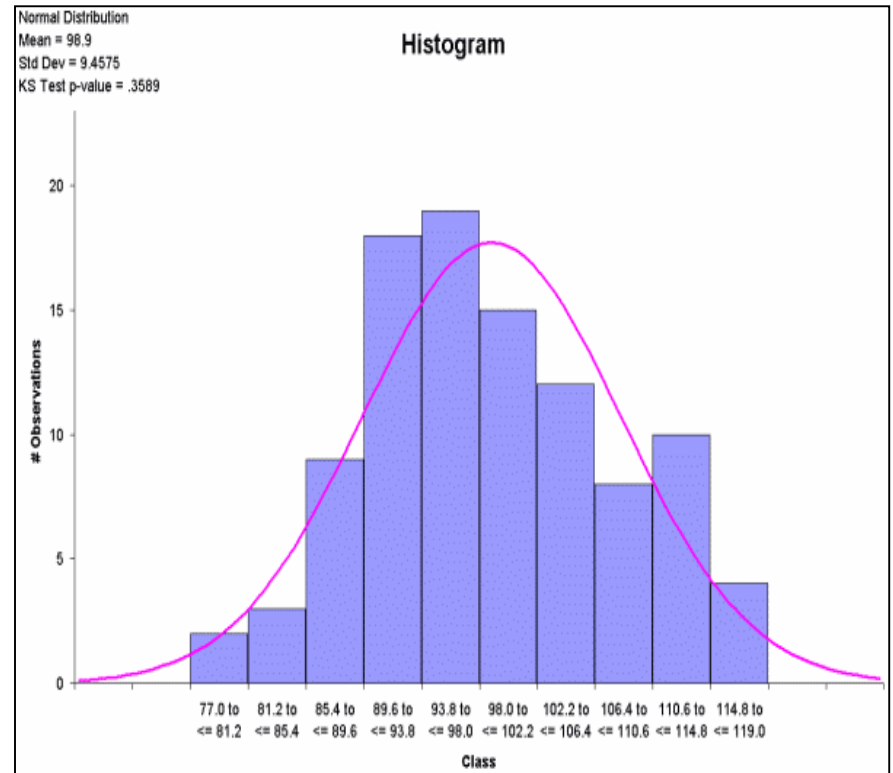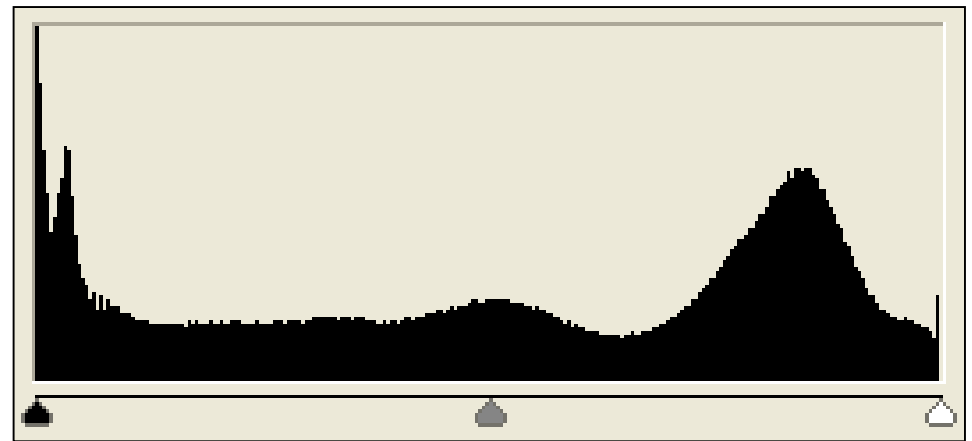- Typically represented as a bar chart:

Image Histograms

- Colour or Intensity distribution.

- Typically:
  - Reduced number of *bins*.
  - Normalization.

- Compressed representation of an image.
  - No spatial information whatsoever!

Colour Histogram

- **As many histograms as axis of the colour space.**

  Ex: RGB Colour space

  - Red Histogram

  - Green Histogram

  - Blue Histogram

- **Combined histogram.**
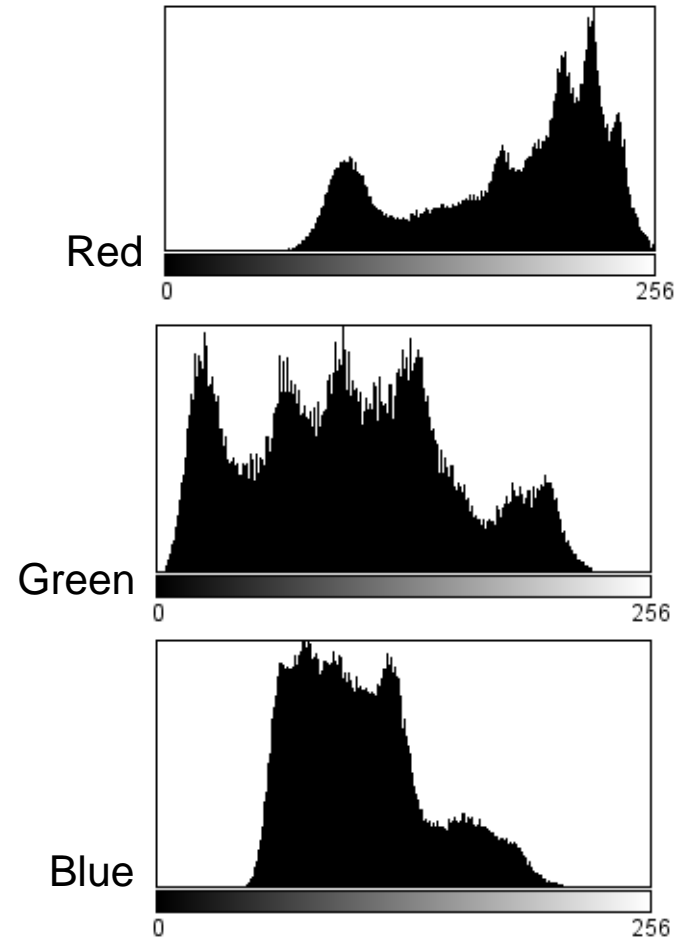
Resources

- R. Gonzalez, and R. Woods – Chapter 2