# VC 10/11 – T5
# Single Pixel Manipulation

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos

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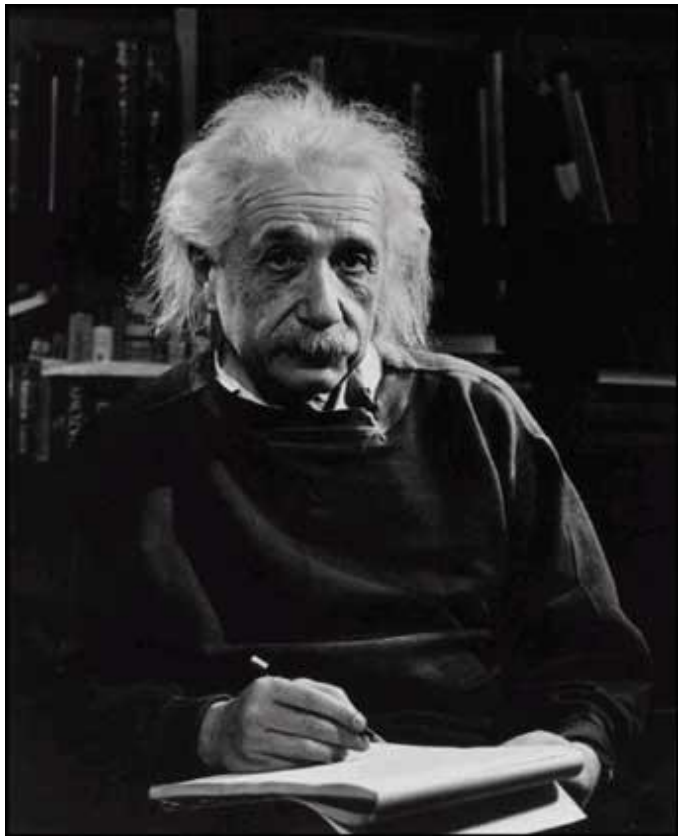
# Outline

- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

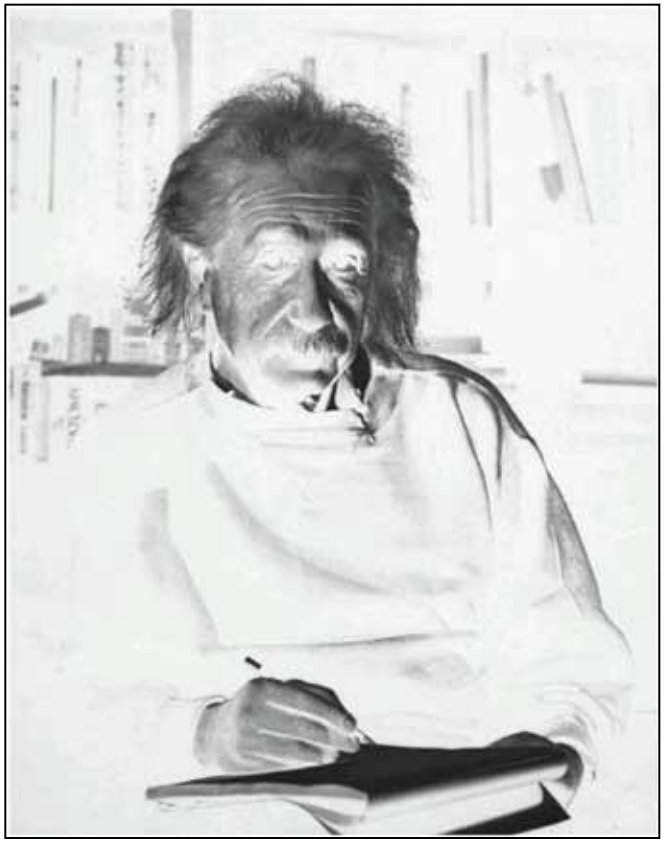
# Topic: Dynamic Range Manipulation

- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

# Manipulation

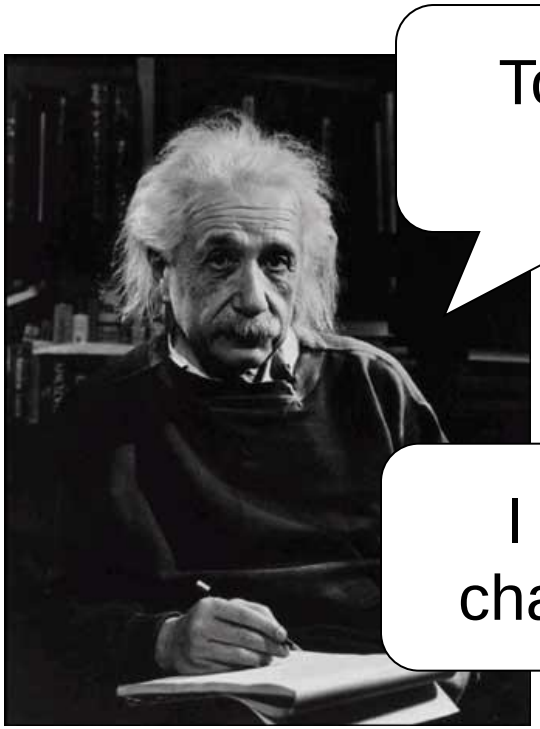


What I see



What I want to see

# Digital Images



To change this...

I need to change this!

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 4 | 7 | 6 | 9 | 8 |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | 0 | 3 | 2 | 5 | 4 | 7 | 6 |
| 5 | 2 | 3 | 0 | 1 | 2 | 3 | 4 | 5 |
| 4 | 3 | 2 | 1 | 0 | 3 | 2 | 5 | 4 |
| | | | 2 | 3 | 0 | 1 | 2 | 3 |
| | | 4 | 3 | 2 | 1 | 0 | 3 | 2 |
| | | 7 | 4 | 5 | 2 | 3 | 0 | 1 |
| 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

What we see

What a computer sees

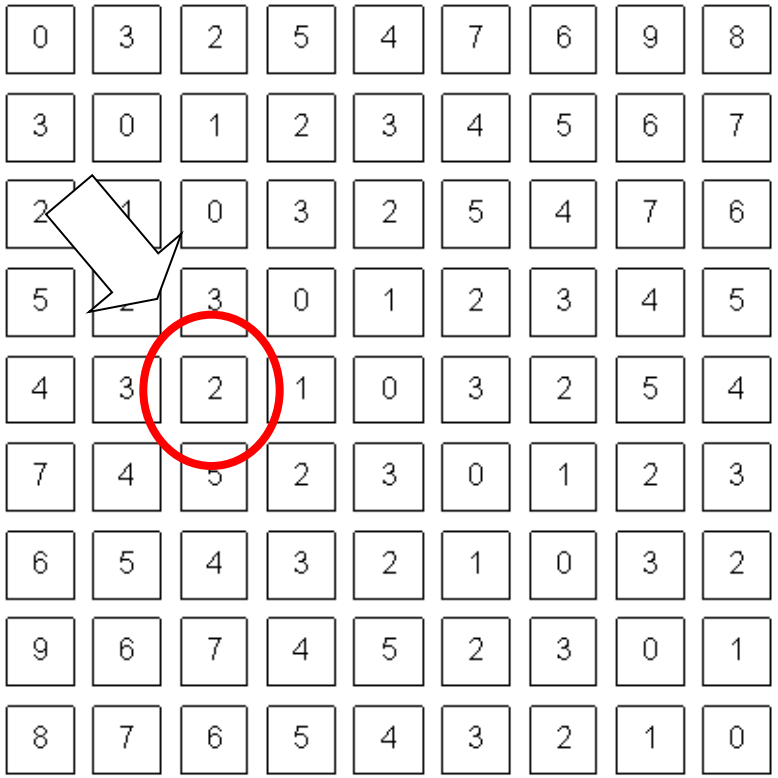
# Pixel Manipulation

- Let's start simple
- I want to change a single Pixel.

$$f(X,Y) = MyNewValue$$

- Or, I can apply a transformation T to all pixels individually.

$$g(x,y) = T\left[f(x,y)\right]$$

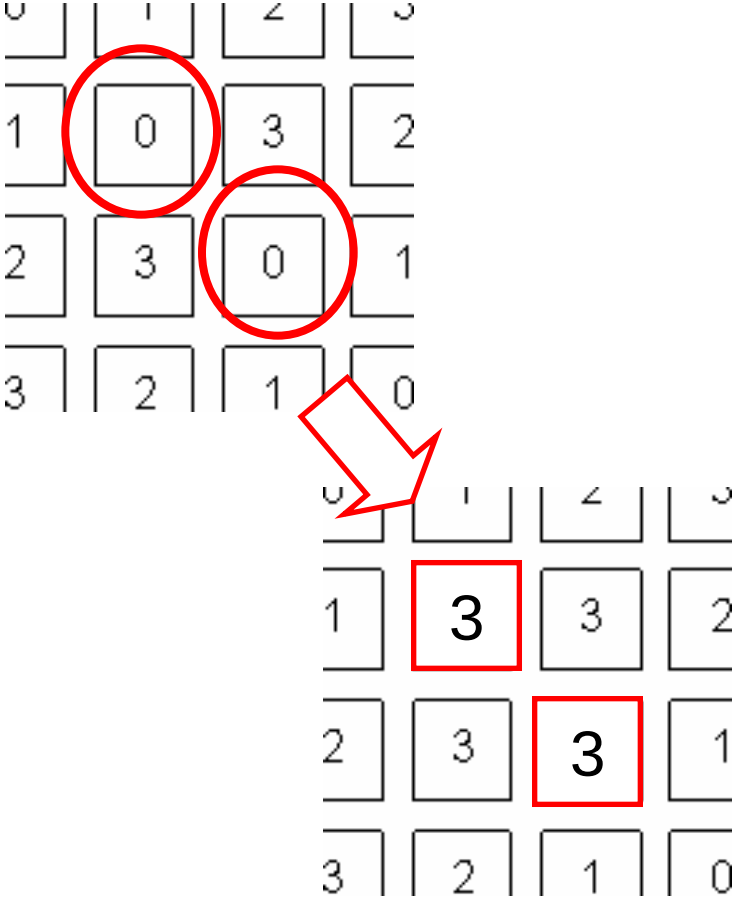


# Image Domain

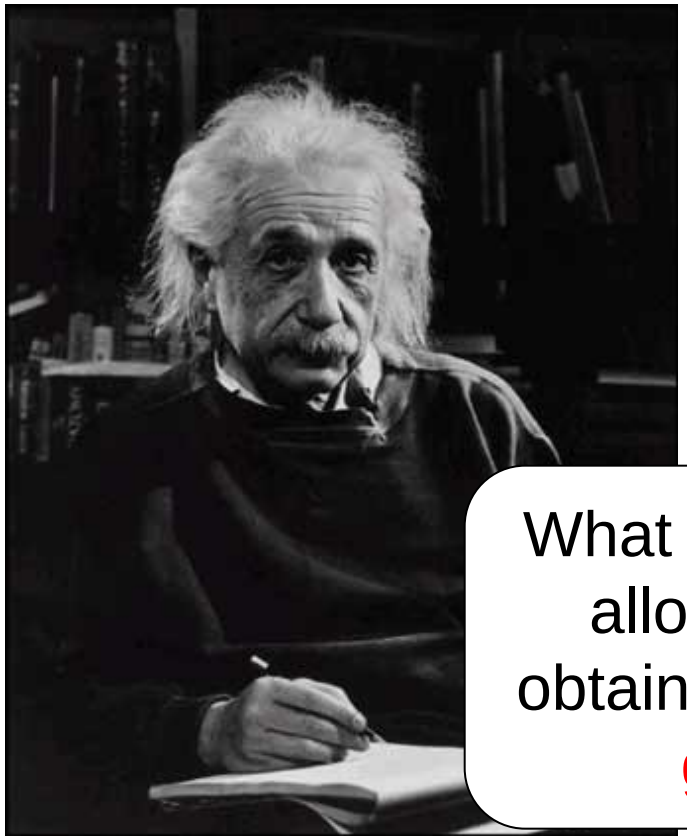
- I am directly changing values of the image matrix.

$$g = T(f)$$

- Image Domain
- So, what is the other possible ‘domain’?



# Image Negative



What operation T allows me to obtain this result?
g=T(f)

What I see

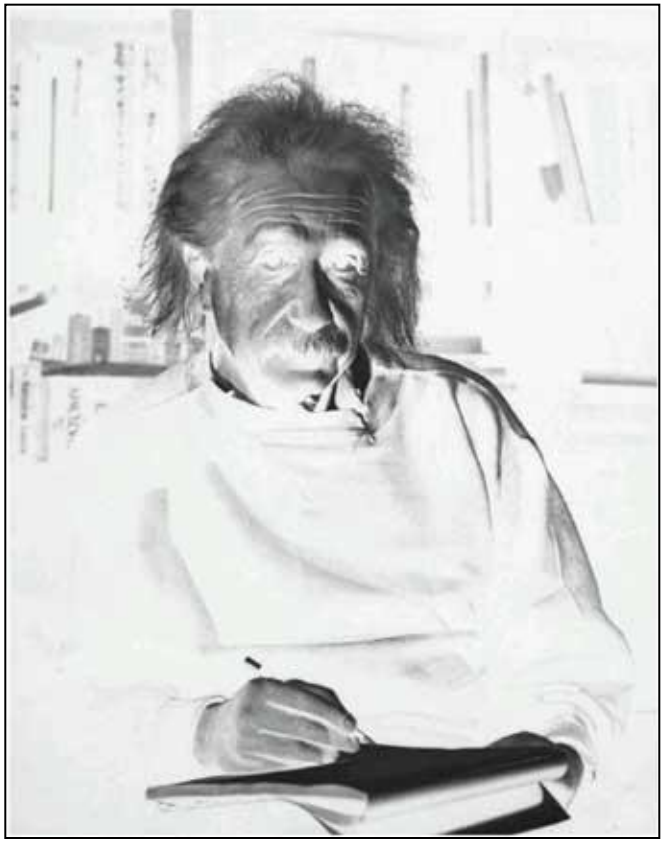
What I want to see

# Image Negative

- Consider the maximum value allowed by quantization (*max).*
- For 8 bits: 255
- Then:

$$g(x,y) = \max - f(x,y)$$

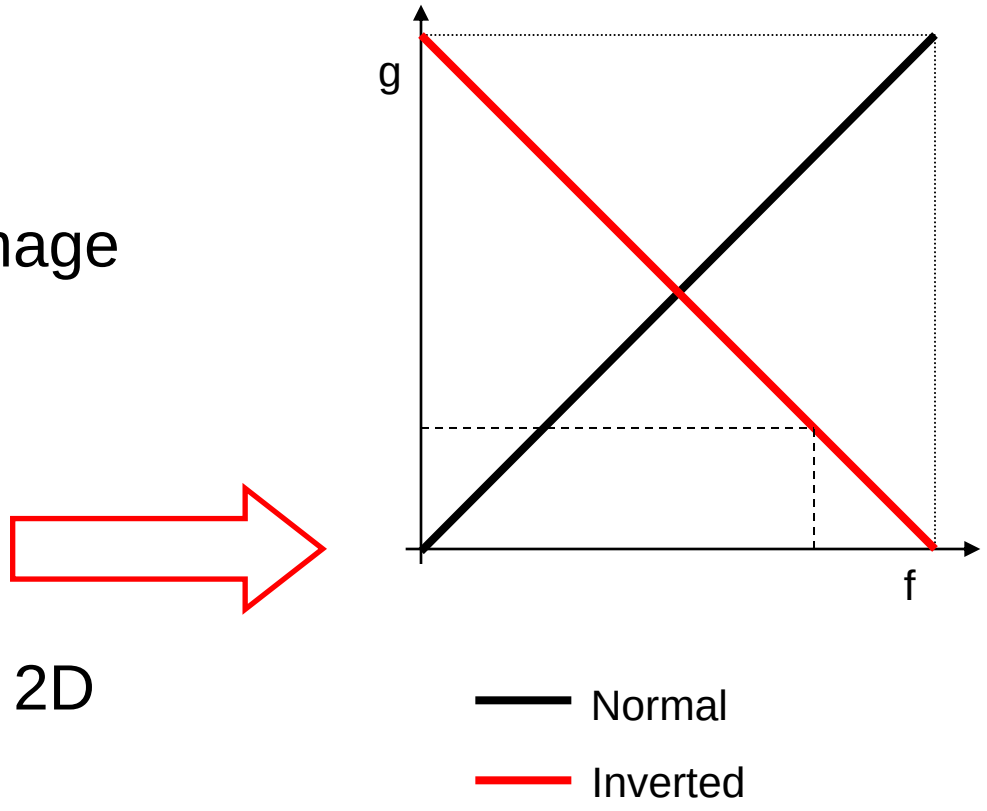
$$g(x,y) = 255 - f(x,y)$$



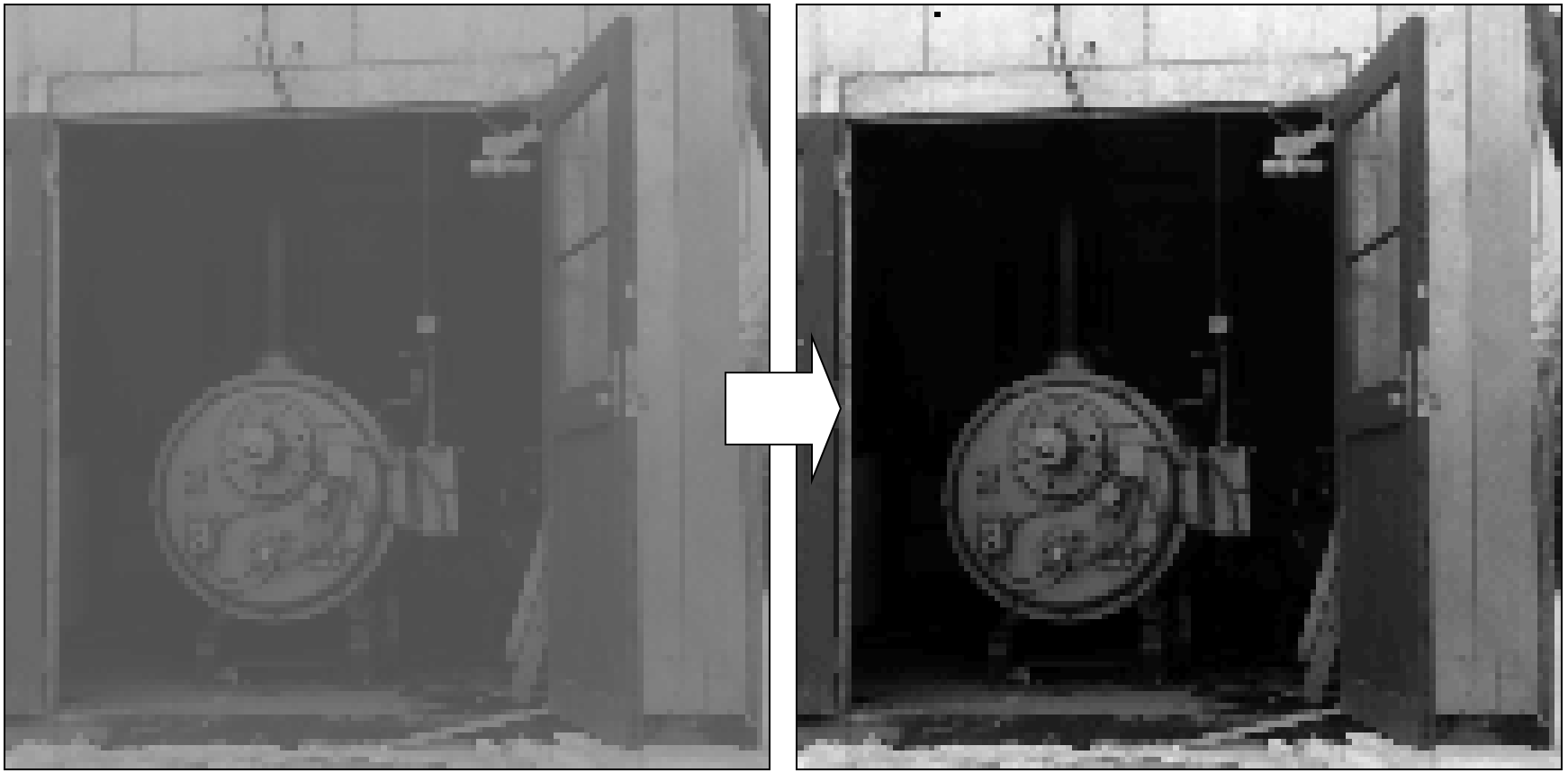
What I want to see

# Dynamic Range Manipulation

- What am I really doing?
  - Changing the response of my image to the received brightness.
- Dynamic Range Manipulation
  - Represented by a 2D Plot.



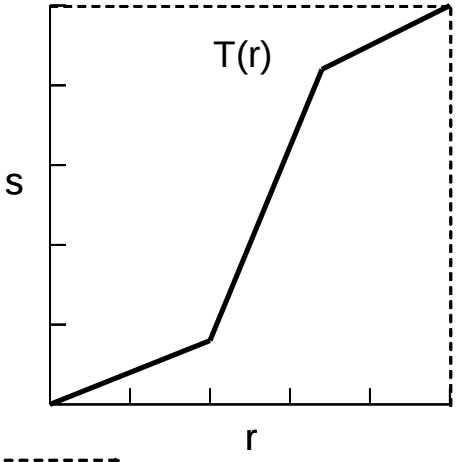
# Why DRM?

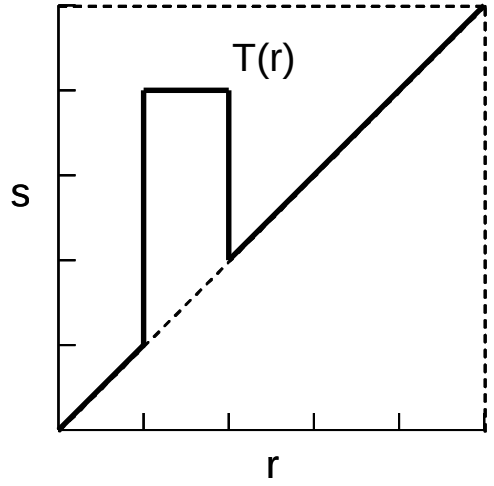


# Why DRM?

# Other DRM functions

- By manipulating our function we can:
  - Enhance generic image visibility.
  - Enhance specific visual features.
  - Use quantization space a lot better.

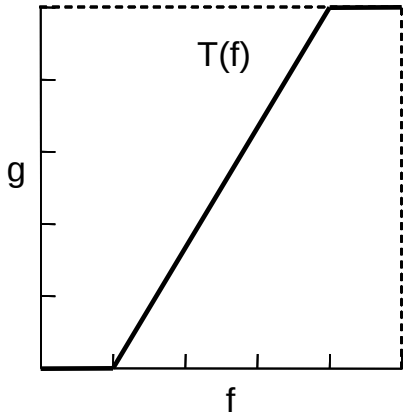


# Contrast Stretching

- 'Stretches' the dynamic range of an image.
- Corrects some image capture problems:
  - Poor illumination, aperture, poor sensor performance, etc.

$$g = \max \frac{f - \min}{\max - \min}$$

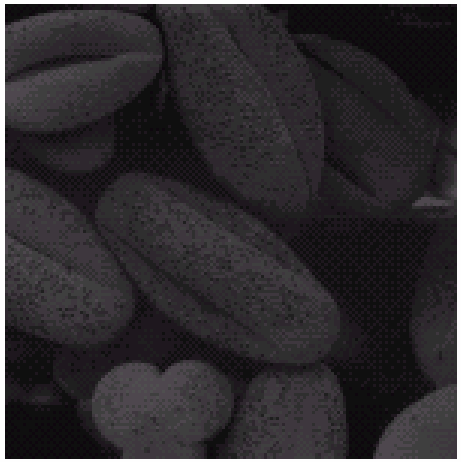


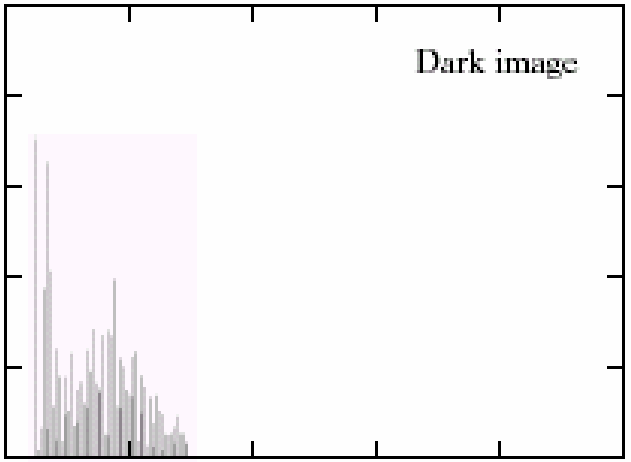

# Histogram Processing

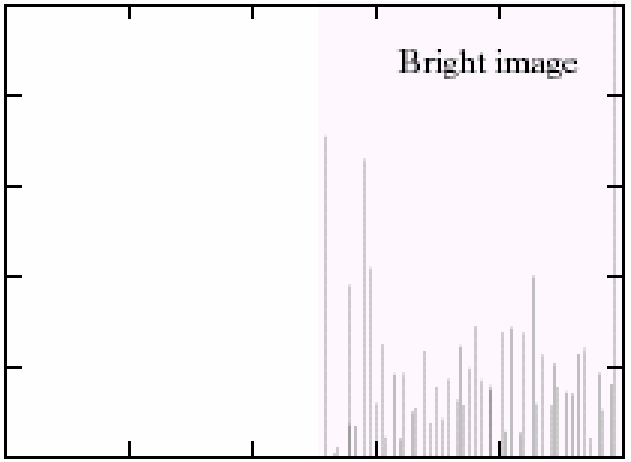
- Histograms give us an idea of how we are using our dynamic range

# Types of Image Histograms

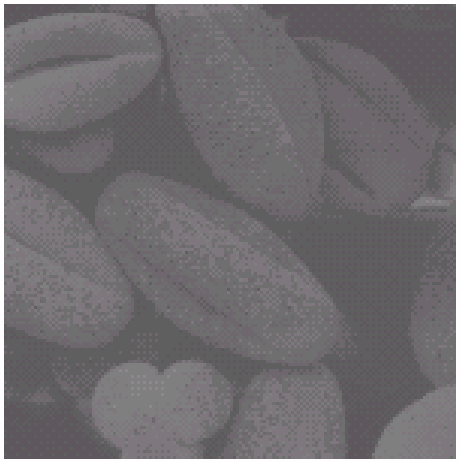
- Images can be classified into types according to their histogram
  - Dark
  - Bright
  - Low-contrast
  - High-contrast

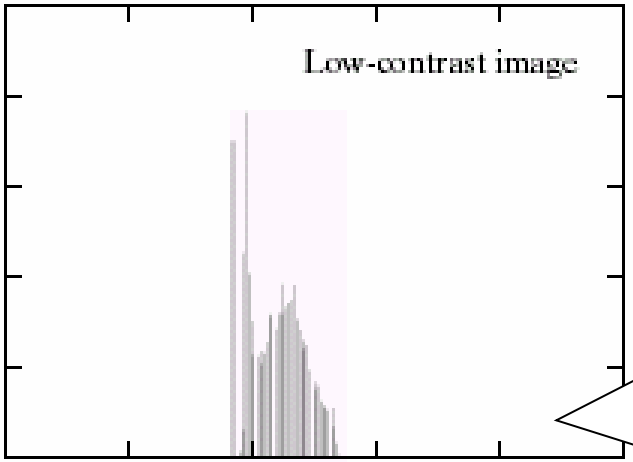


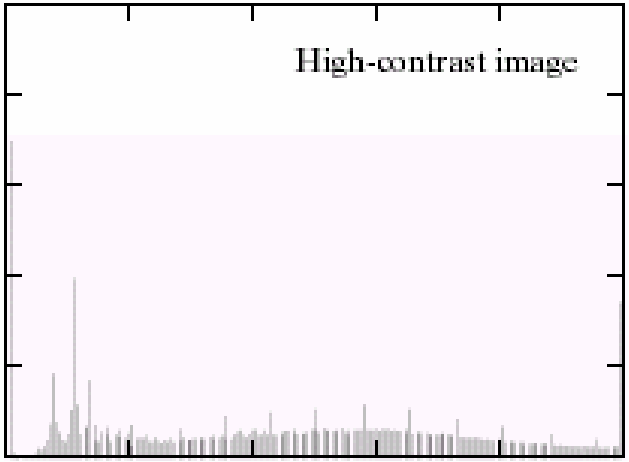


# Types of Image Histograms





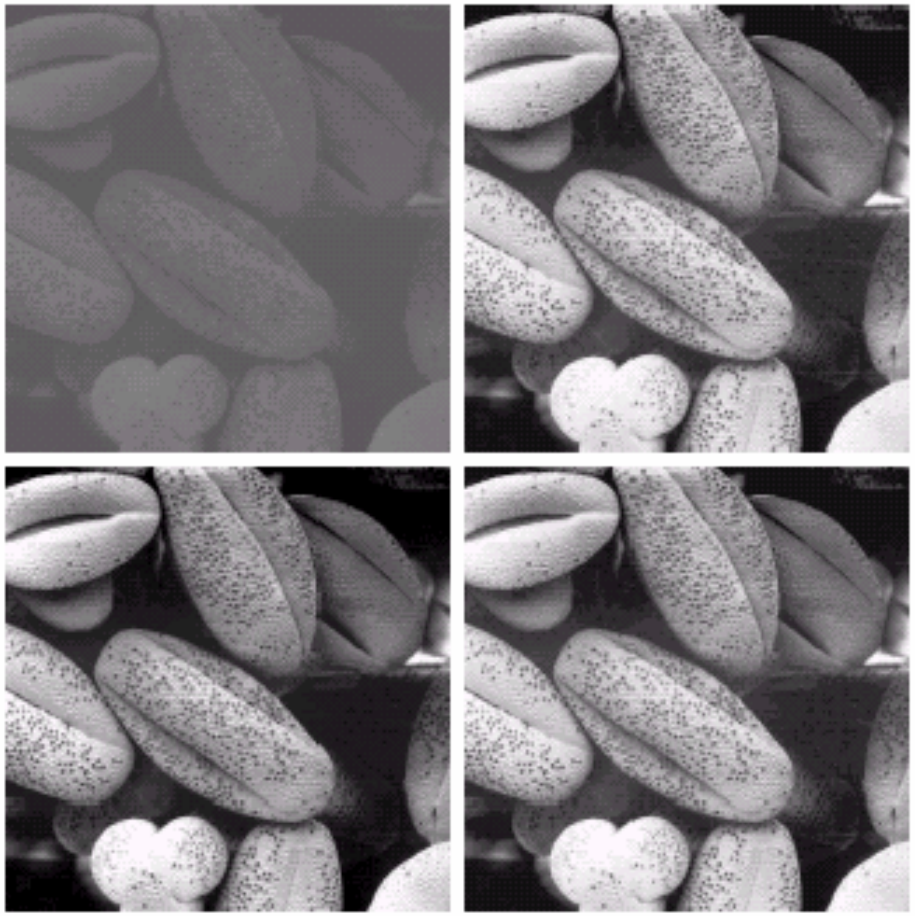




I can manipulate this using single Pixel operations!

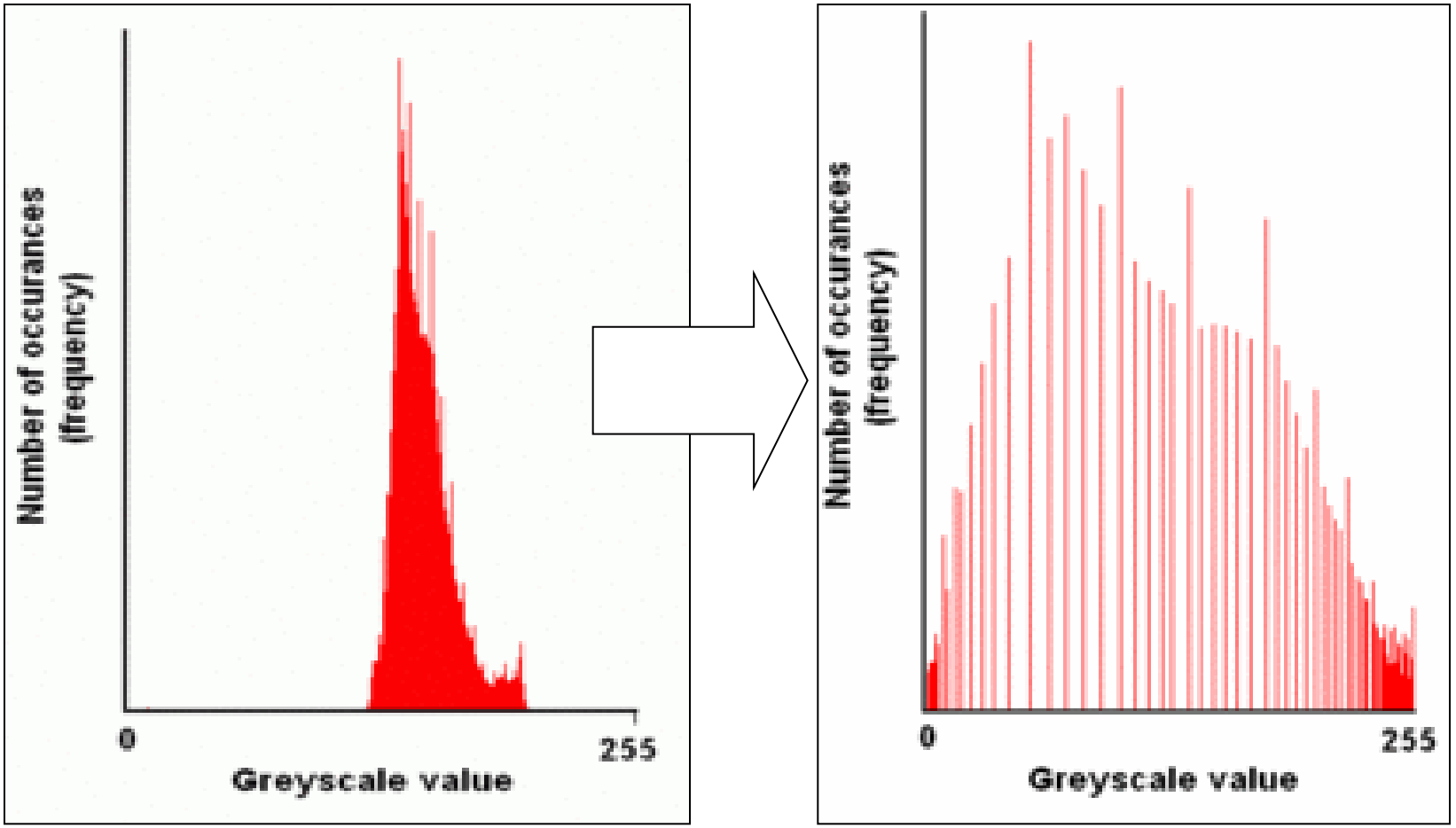
# Histogram Equalization

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j)$$

- Objective:
  - Obtain a ‘flat’ histogram.
  - Enhance visual contrast.
- Digital histogram
  - Result is a ‘flat-ish’ histogram.
  - Why?



# Histogram Equalization

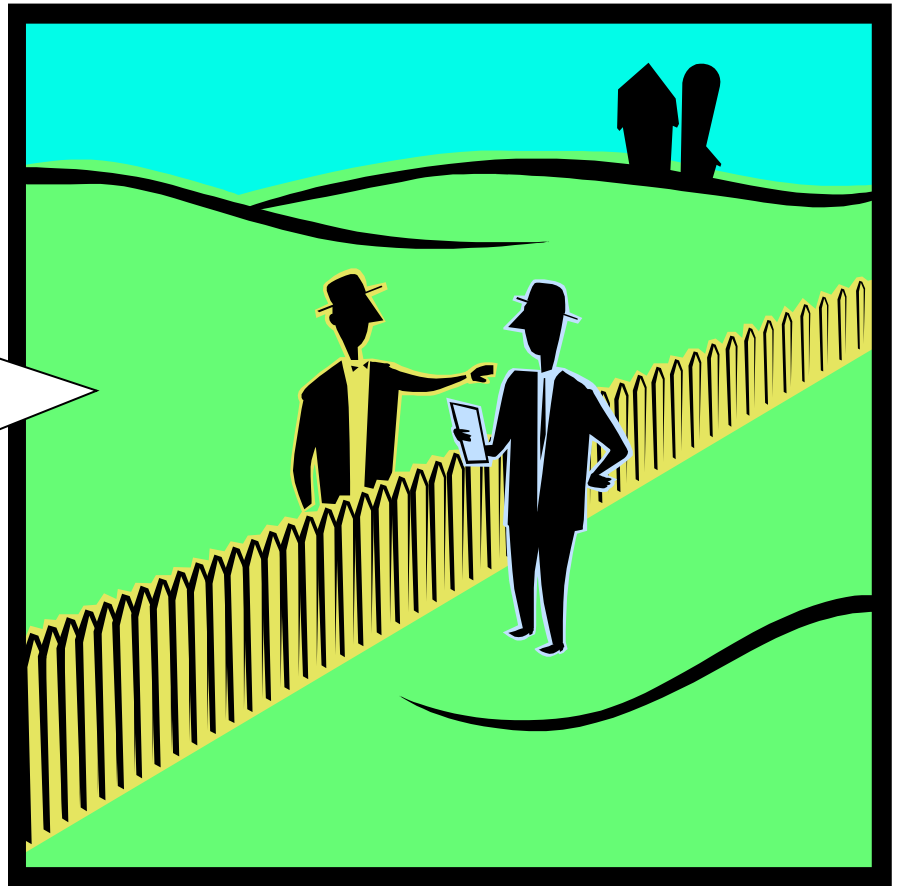


# Topic: Neighborhoods and Connectivity

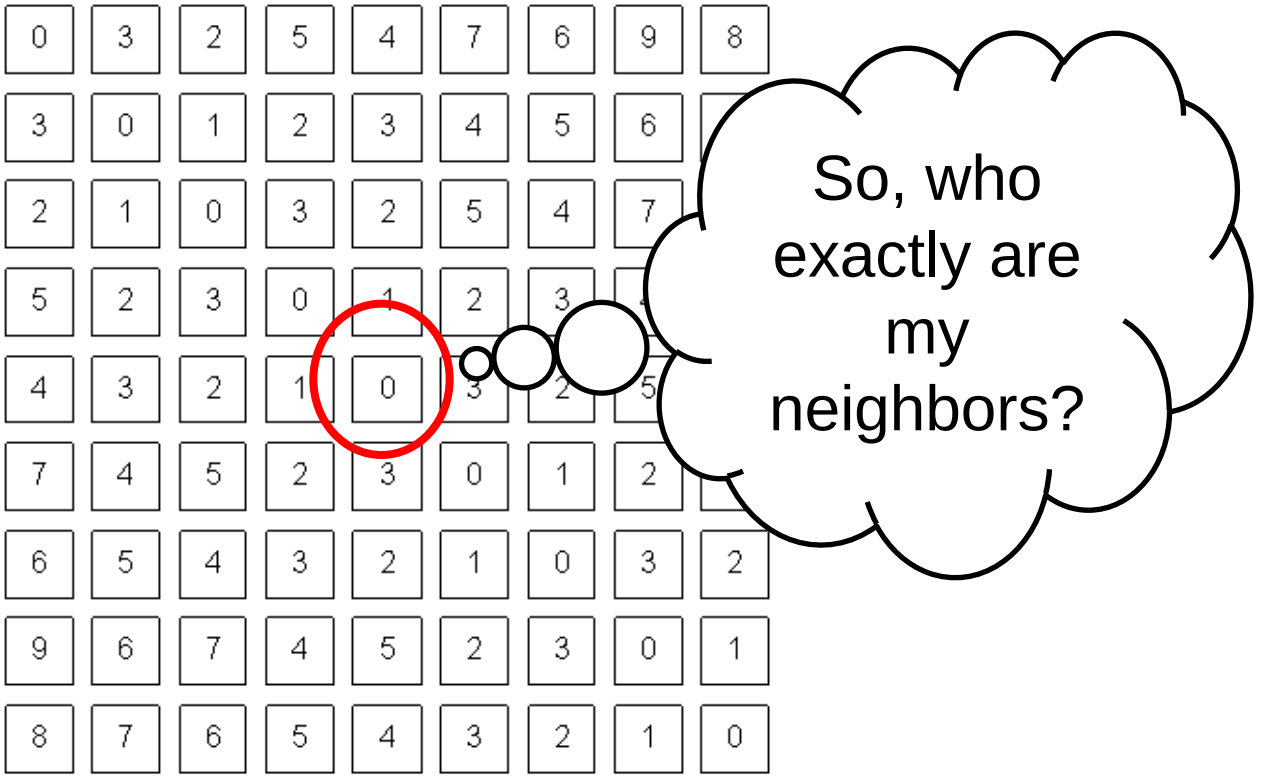
- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

# Neighbors

Why do we care at all?



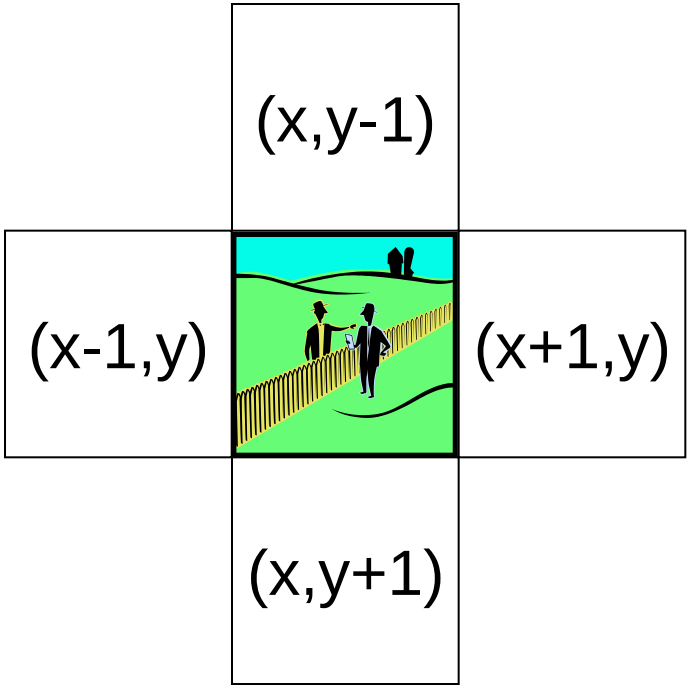
# Digital Images




What a computer sees

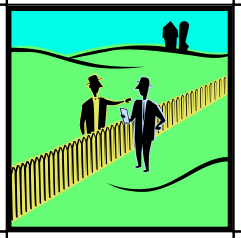
# 4-Neighbors

- A pixel p at (x,y) has 2 horizontal and 2 vertical neighbors:
  - (x+1,y), (x-1,y), (x,y+1), (x,y-1)
  - $N_4(p)$: Set of the 4-neighbors of p.
- Limitations?



# 8-Neighbors

- A pixel has 4 diagonal neighbors
  - (x+1,y+1), (x+1,y-1), (x-1,y+1), (x-1,y-1)
  - $N_D(p)$: Diagonal set of neighbors
- $N_8(p) = N_4(p)+N_D(p)$
- Limitations?

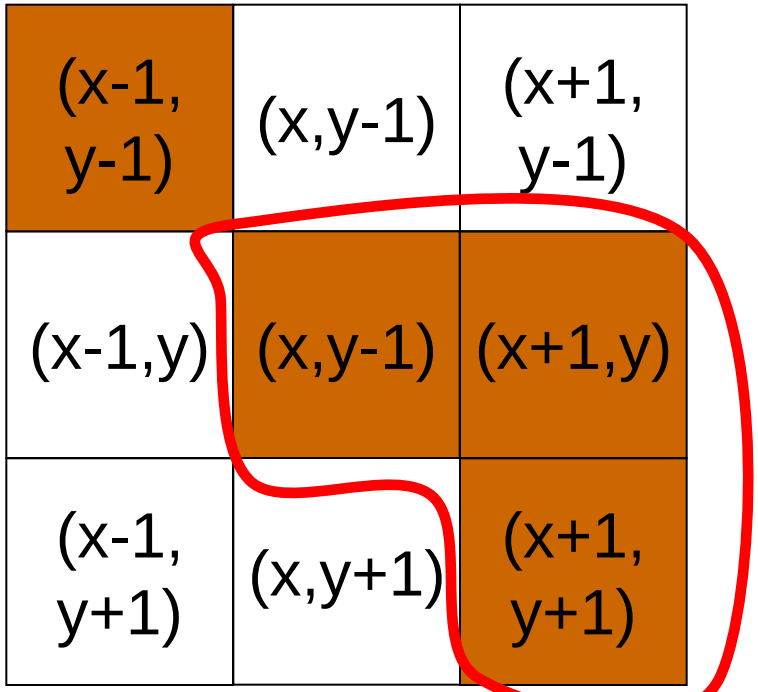
| | | |
|---|---|---|
| (x-1, y-1) | (x,y-1) | (x+1, y-1) |
| (x-1,y) |  | (x+1,y) |
| (x-1, y+1) | (x,y+1) | (x+1, y+1) |

# Connectivity

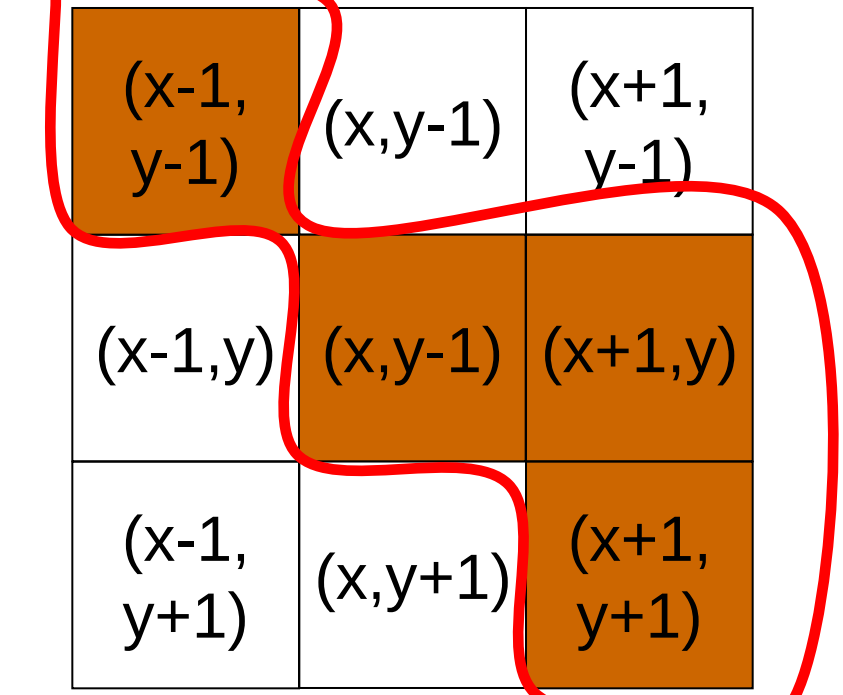
- Two pixels are connected if:
  - They are neighbors (i.e. adjacent in some sense -- e.g. $N_4(p)$, $N_8(p)$, …)
  - Their gray levels satisfy a specified criterion of similarity (e.g. equality, …)

| | | |
|---|---|---|
| (x-1, y-1) | (x,y-1) | (x+1, y-1) |
| (x-1,y) | (x,y-1) | (x+1,y) |
| (x-1, y+1) | (x,y+1) | (x+1, y+1) |

# 4 and 8-Connectivity

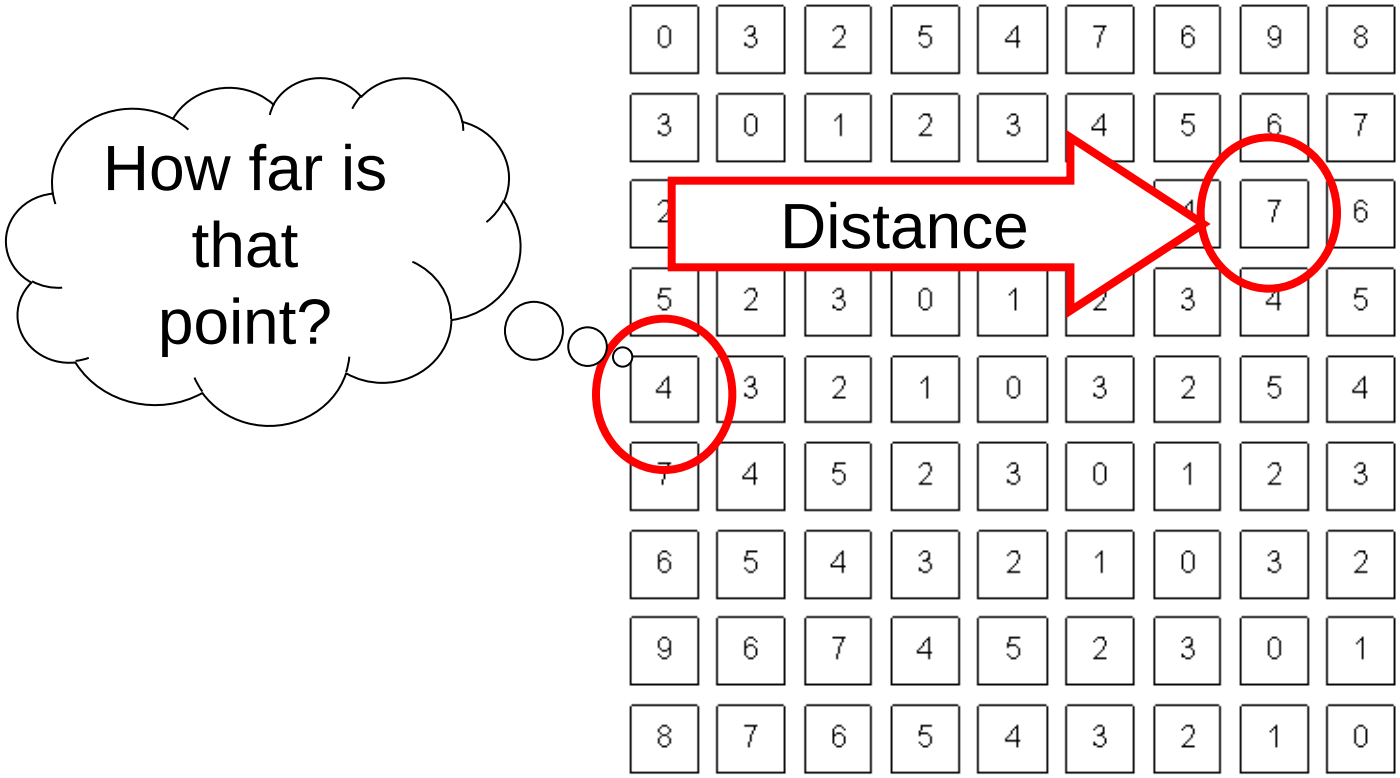



4-Connectivity




8-Connectivity

# Distances


How far is that point?
Distance
0 3 2 5 4 7 6 9 8
3 0 1 2 3 4 5 6 7
7 6
5 2 3 0 1 2 3 4 5
4 3 2 1 0 3 2 5 4
4 5 2 3 0 1 2 3
6 5 4 3 2 1 0 3 2
9 6 7 4 5 2 3 0 1
8 7 6 5 4 3 2 1 0

# D4 Distance

- $D_4$ distance (city-block distance):
  - $D_4(p,q) = |x-s| + |y-t|$
  - forms a diamond centered at (x,y)
  - e.g. pixels with $D_4 \leq 2$ from p

| | | | | |
|---|---|---|---|---|
| | | 2 | | |
| | 2 | 1 | 2 | |
| 2 | 1 | 0 | 1 | 2 |
| | 2 | 1 | 2 | |
| | | 2 | | |

$D_4 = 1$ are the 4-neighbors of p

# D8 Distance

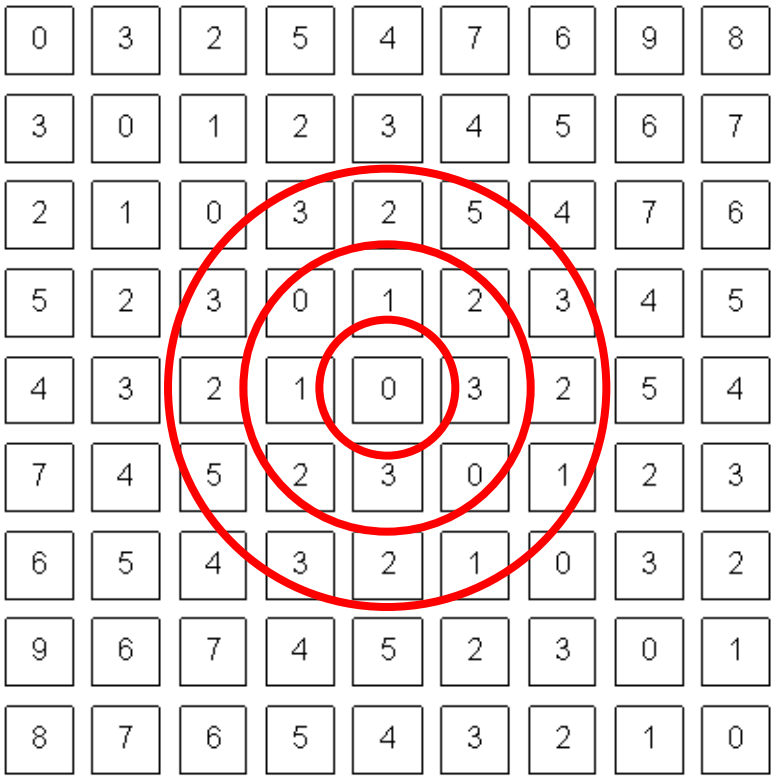
- $D_8$ distance (chessboard distance):
  - $D_8(p,q) = \max(|x-s|,|y-t|)$
  - Forms a square centered at p
  - e.g. pixels with $D_8 \leq 2$ from p

| | | | | |
|---|---|---|---|---|
| 2 | 2 | 2 | 2 | 2 |
| 2 | 1 | 1 | 1 | 2 |
| 2 | 1 | 0 | 1 | 2 |
| 2 | 1 | 1 | 1 | 2 |
| 2 | 2 | 2 | 2 | 2 |

$D_8 = 1$ are the 8-neighbors of p

# Euclidean Distance

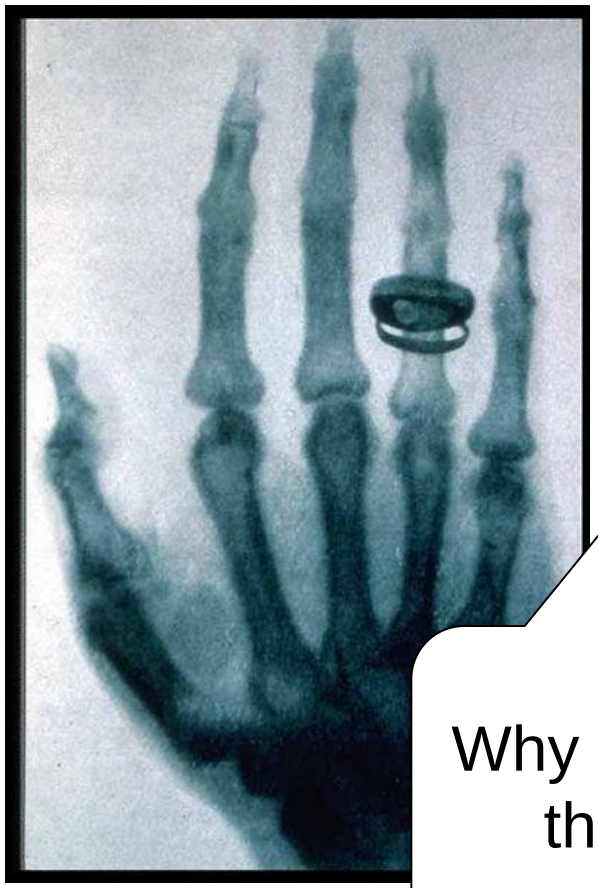
- Euclidean distance:
  - $D_e(p,q) = [(x-s)^2 + (y-t)^2]^{1/2}$
  - Points (pixels) having a distance less than or equal to r from (x,y) are contained in a disk of radius r centered at (x,y).



# Topic: Image Arithmetic

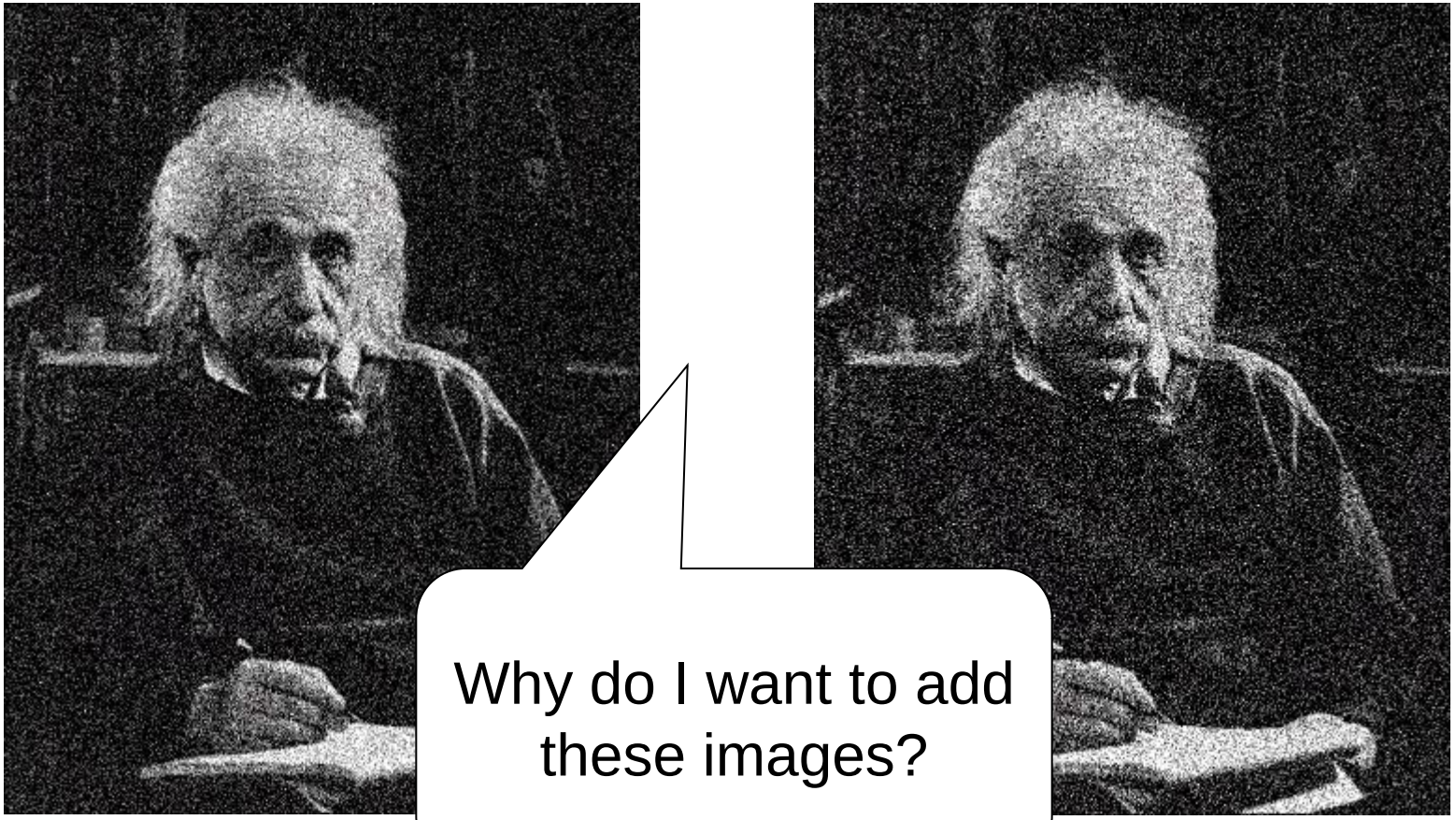
- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

# Arithmetic operations between images

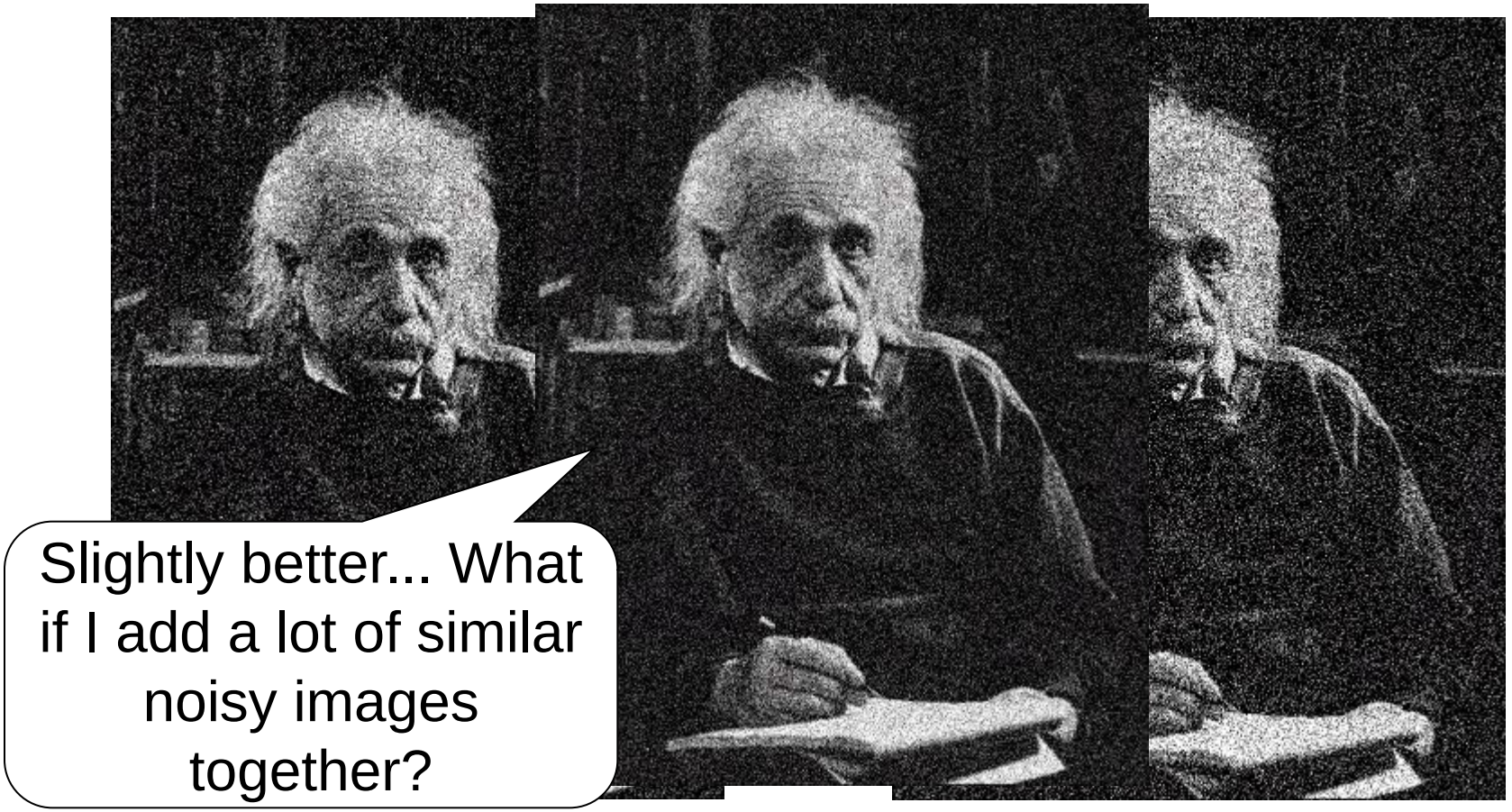


Why do I want to add these images?

# Arithmetic operations between images



# Arithmetic operations between images



# Image Arithmetic

- Image 1: a(x,y)
- Image 2: b(x,y)
- Result: c(x,y) = a(x,y) OPERATION b(x,y)
- Possibilities:
  - Addition
  - Subtraction
  - Multiplication
  - Division
  - Etc..

Why is this useful? What problems can happen?

# Example

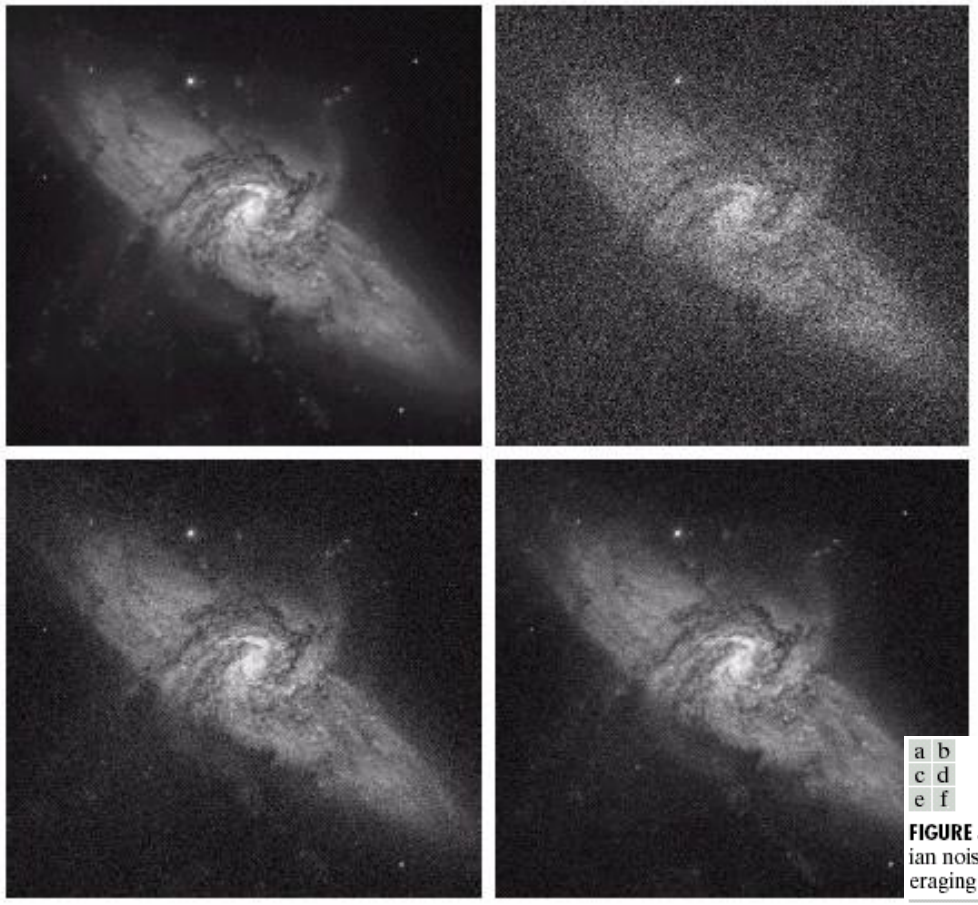


Image Addition

a b
c d
e f

**FIGURE 3.30** (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64$, and 128 noisy images. (Original image courtesy of NASA.)

# Logic Operations

- Binary Images
- We can use Boolean Logic
- Operations:
  - AND
  - OR
  - NOT

More on this when we study mathematical morphology.

# Topic: Example: Background Subtraction

- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

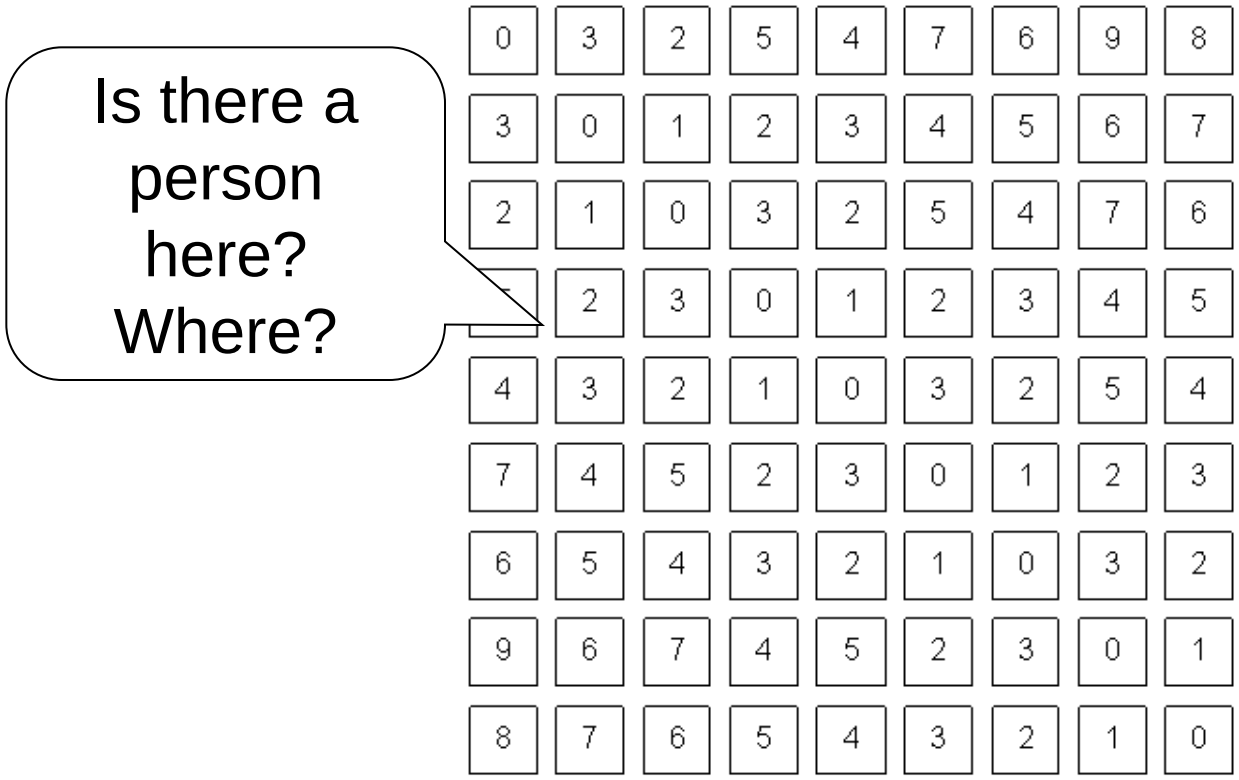
# Example: Background Subtraction

- Image arithmetic is simple and powerful.

Is there a person here? Where?

# Background Subtraction

- Remember: We can only see numbers!



# Background Subtraction

- What if I know this?

# Background Subtraction

- Subtract!
- Limitations?

# Background Subtraction

- Objective:
  - Separate the foreground objects from a static background.
- Large variety of methods:
  - Mean & Threshold [CD04]
  - Normalized Block Correlation [Mats00]
  - Temporal Derivative [Hari98]
  - Single Gaussian [Wren97]
  - Mixture of Gaussians [Grim98]

Segmentation!! More on this later.

# Resources

- R. Gonzalez, and R. Woods – Chapter 2
- R. Gonzalez, and R. Woods – Chapter 4
- K. Toyama, J. Krumm, B. Brumitt, and B. Meyers, “Wallflower: Principles and practice of background maintenance”, in Proc. of IEEE ICCV, Corfu, Greece, 1999.