Computer Vision – TP5
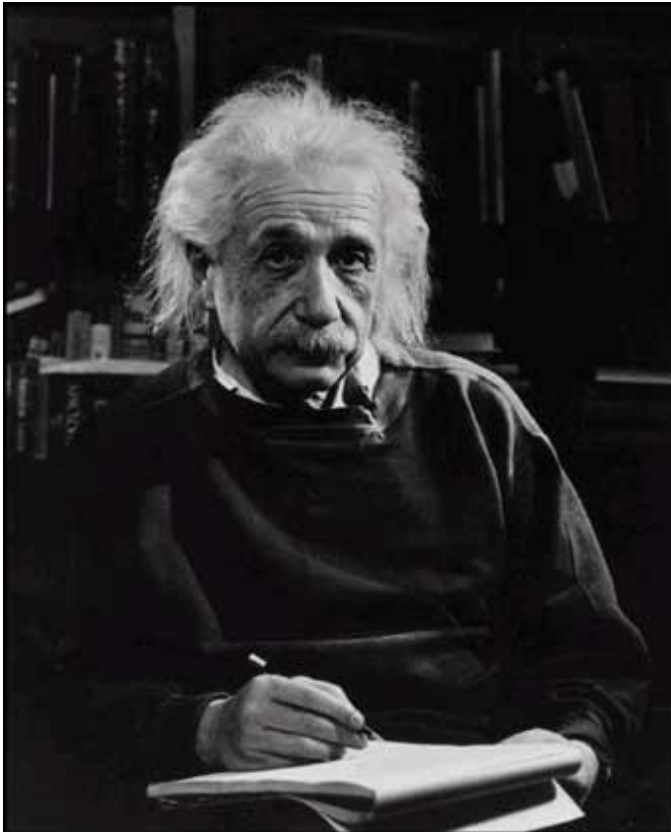# Single Pixel Manipulation

Miguel Tavares Coimbra

Outline

- Dynamic Range Manipulation

- Neighborhoods and Connectivity
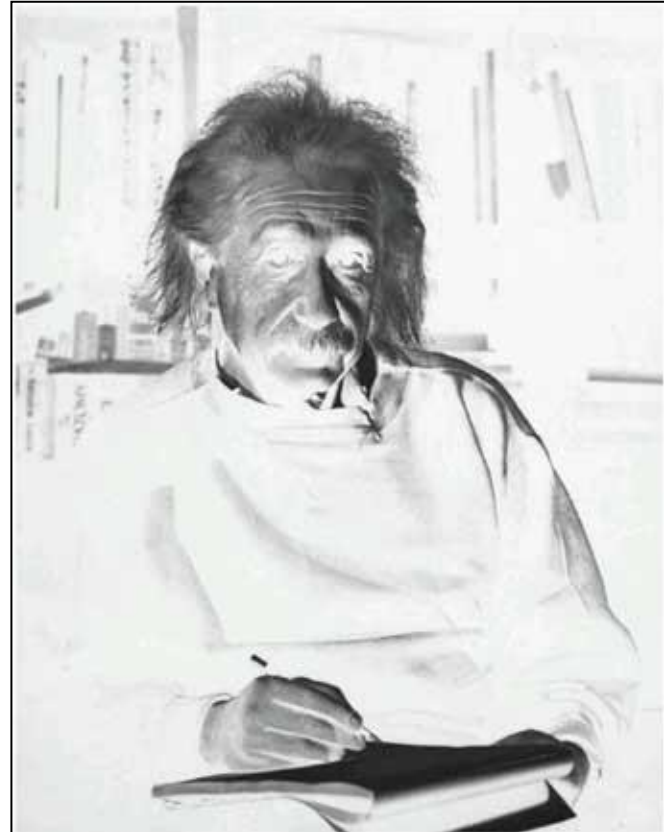
- Image Arithmetic

- Example: Background Subtraction

Topic: Dynamic Range Manipulation

- Dynamic Range Manipulation

- Neighborhoods and Connectivity

- Image Arithmetic
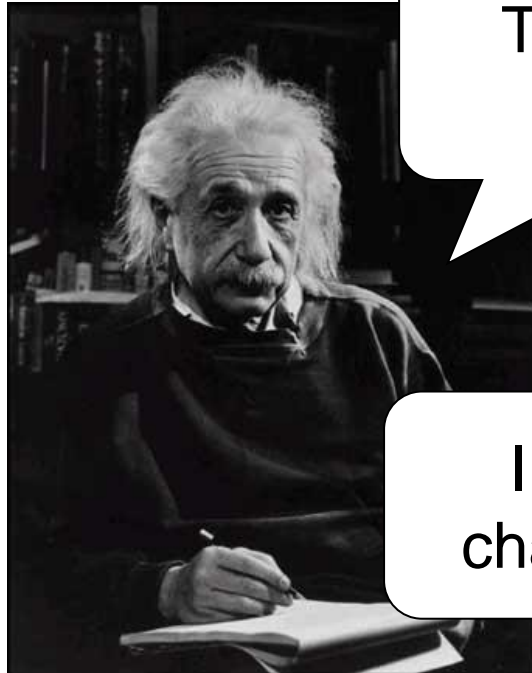
- Example: Background Subtraction

Manipulation

What I see

What I want to see

U.PORTO FC

Digital Images
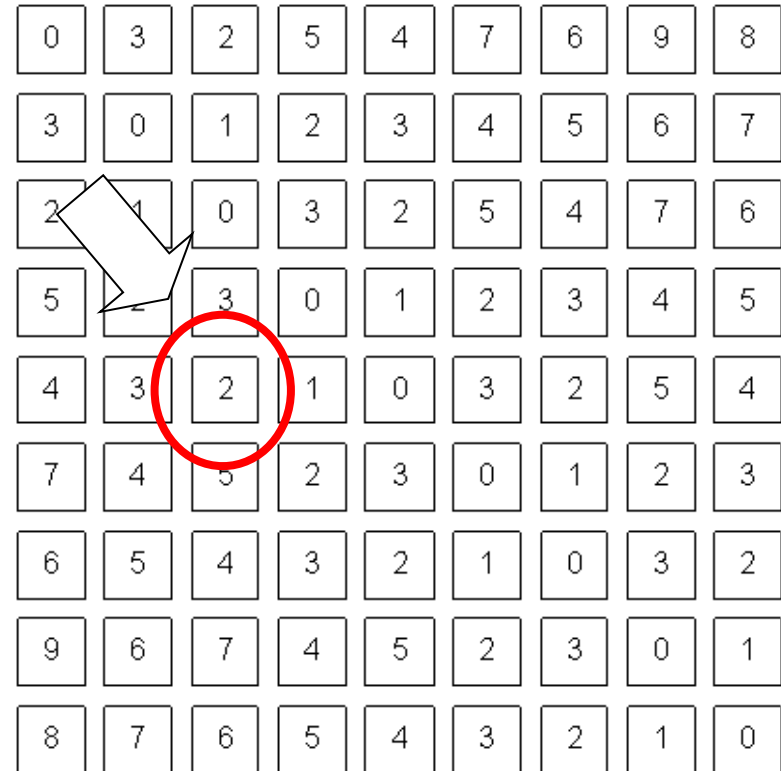

What we see

What a computer sees

Pixel Manipulation

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

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

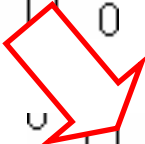- Or, I can apply a transformation **T** to all pixels individually.

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

Image Domain

- I am directly changing values of the image matrix.

$$g = T(f)$$

- Image Domain

- So, what is the other possible 'domain'?
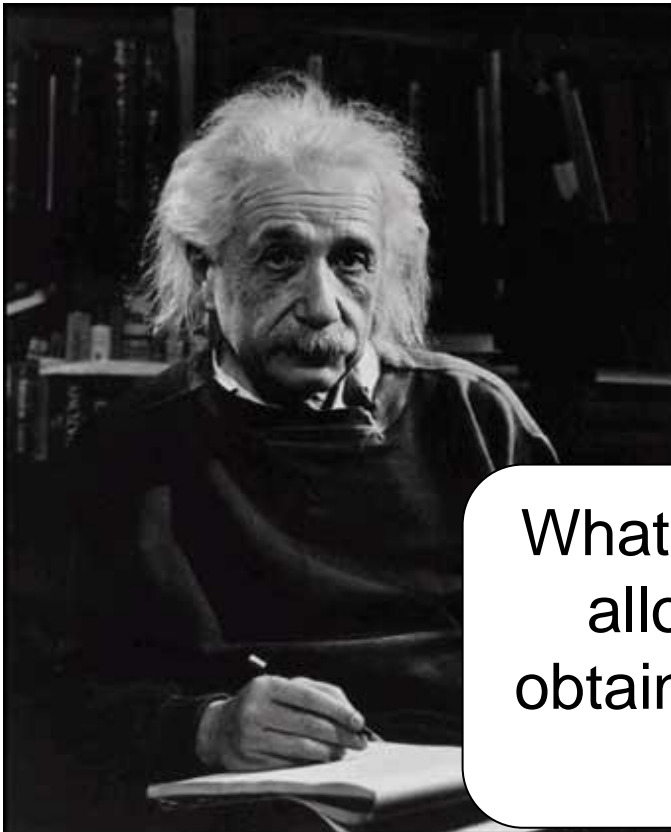
Image Negative

What I see

What I <u>want</u> to see
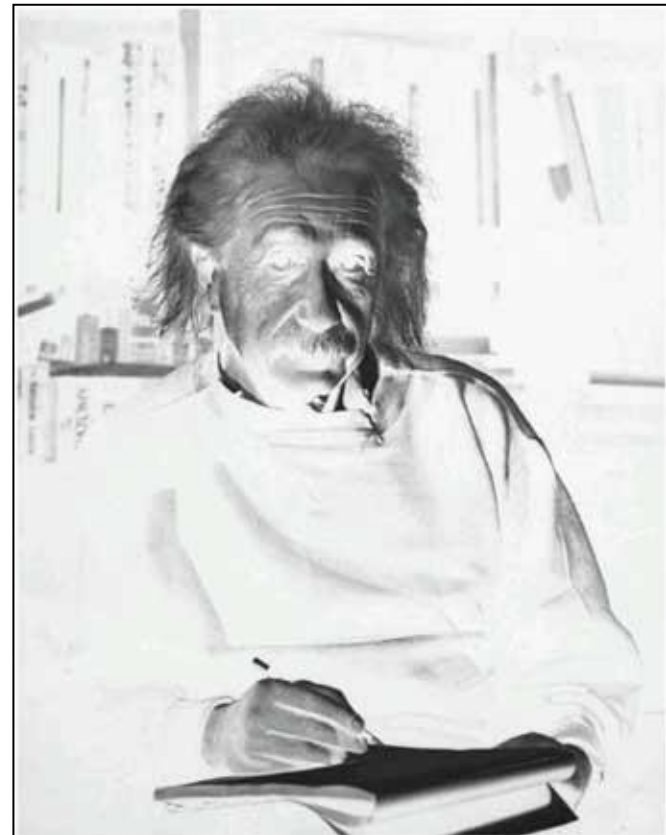
Image Negative

- Consider the maximum value allowed by quantization (*max*)
- For 8 bits: 255
- Then:
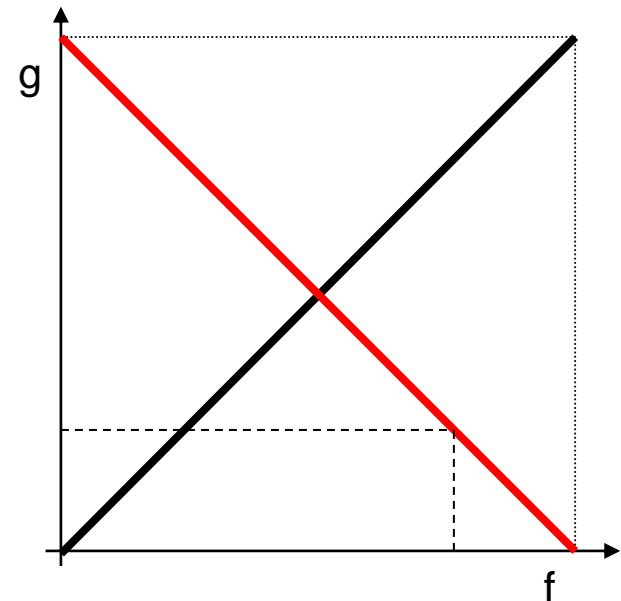
$$g(x, y) = \max - f(x, y)$$
$$g(x, y) = 255 - f(x, y)$$

What I <u>want</u> 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

——— Normal

——— Inverted

Example – Contrast Stretching

Example – Contrast Stretching
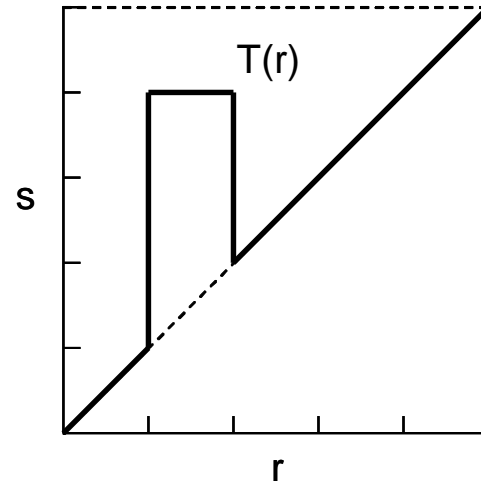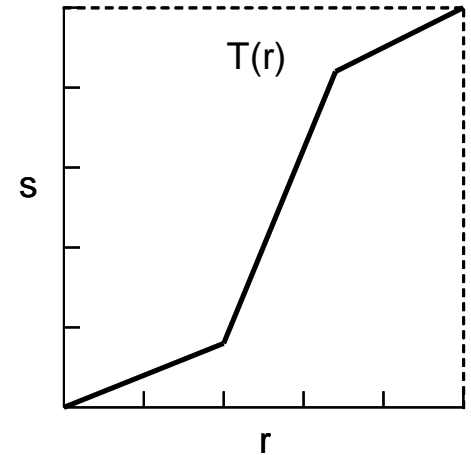
Example – Hist. Equalization

Example – Hist. Equalization
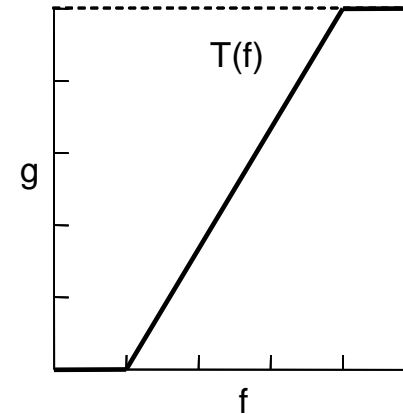
Other DRM functions

- ## 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.

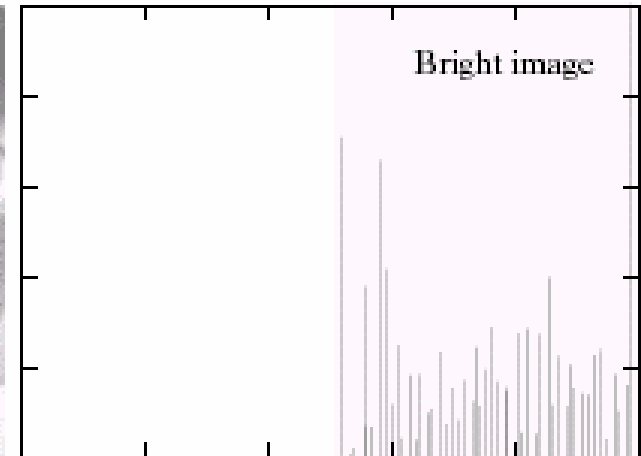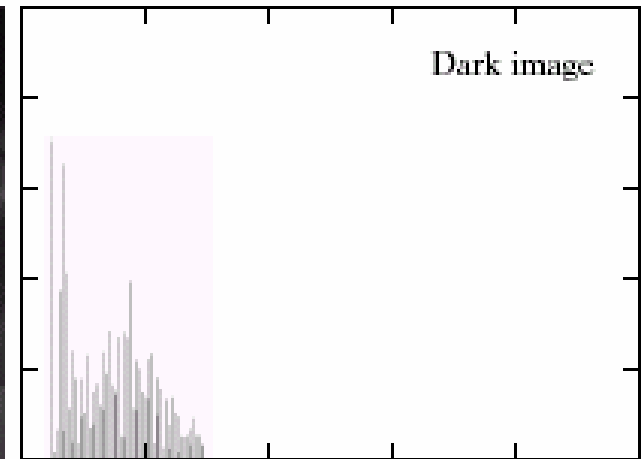$$g = 255 \frac{f - \min}{\max - \min}$$

Histogram Processing

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

> What if I want a different histogram for my image?

Types of Image Histograms

- **Images can be classified into types according to their histogram**
  - Dark
  - Bright
  - Low-contrast
  - High-contrast
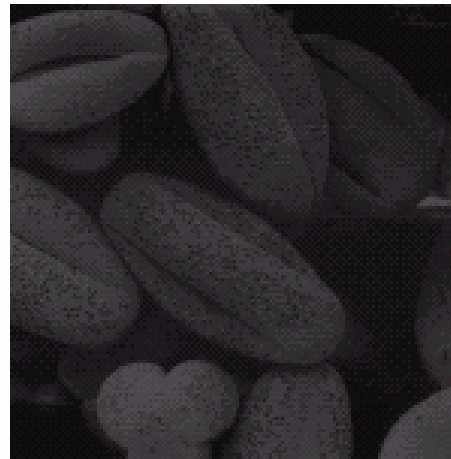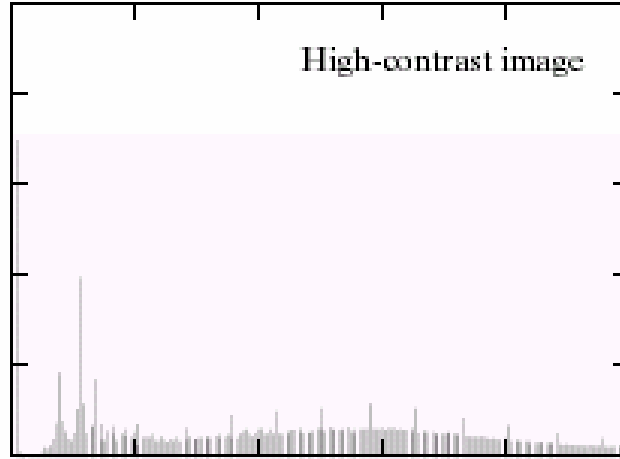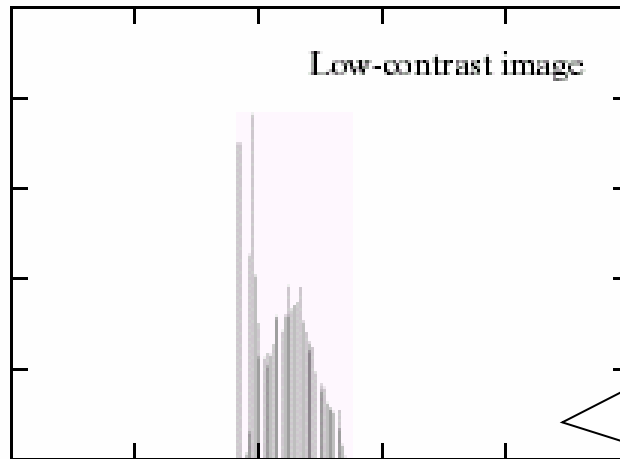
Types of Image Histograms

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?
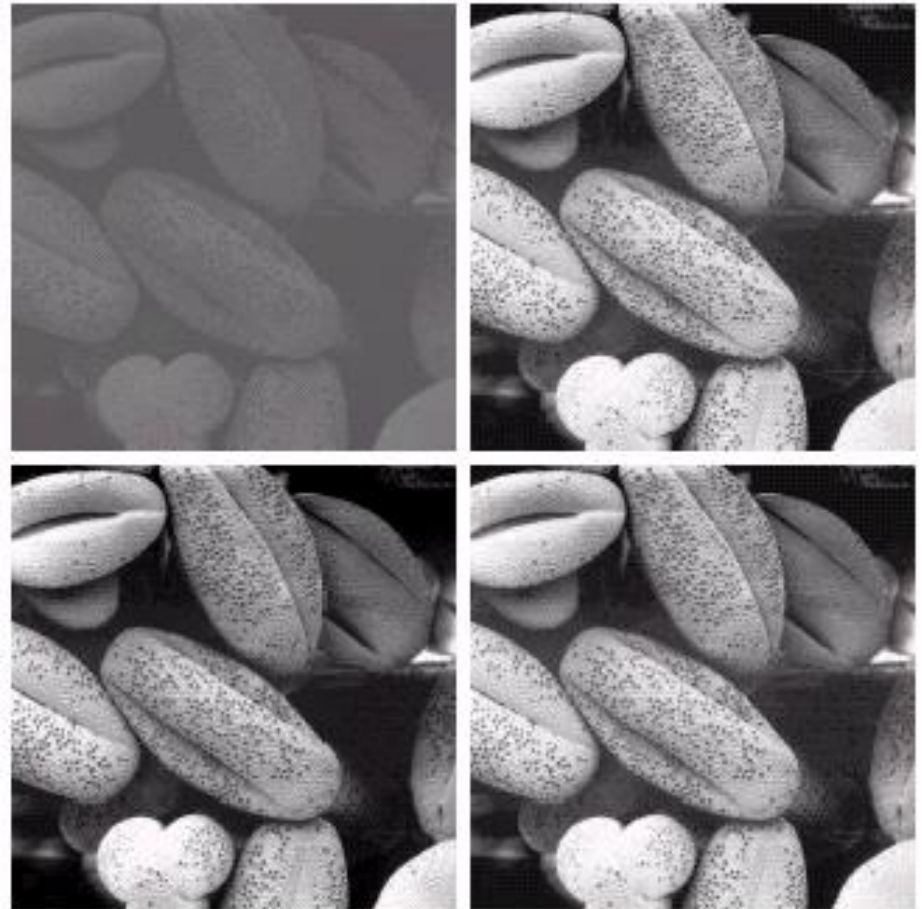
Histogram Equalization
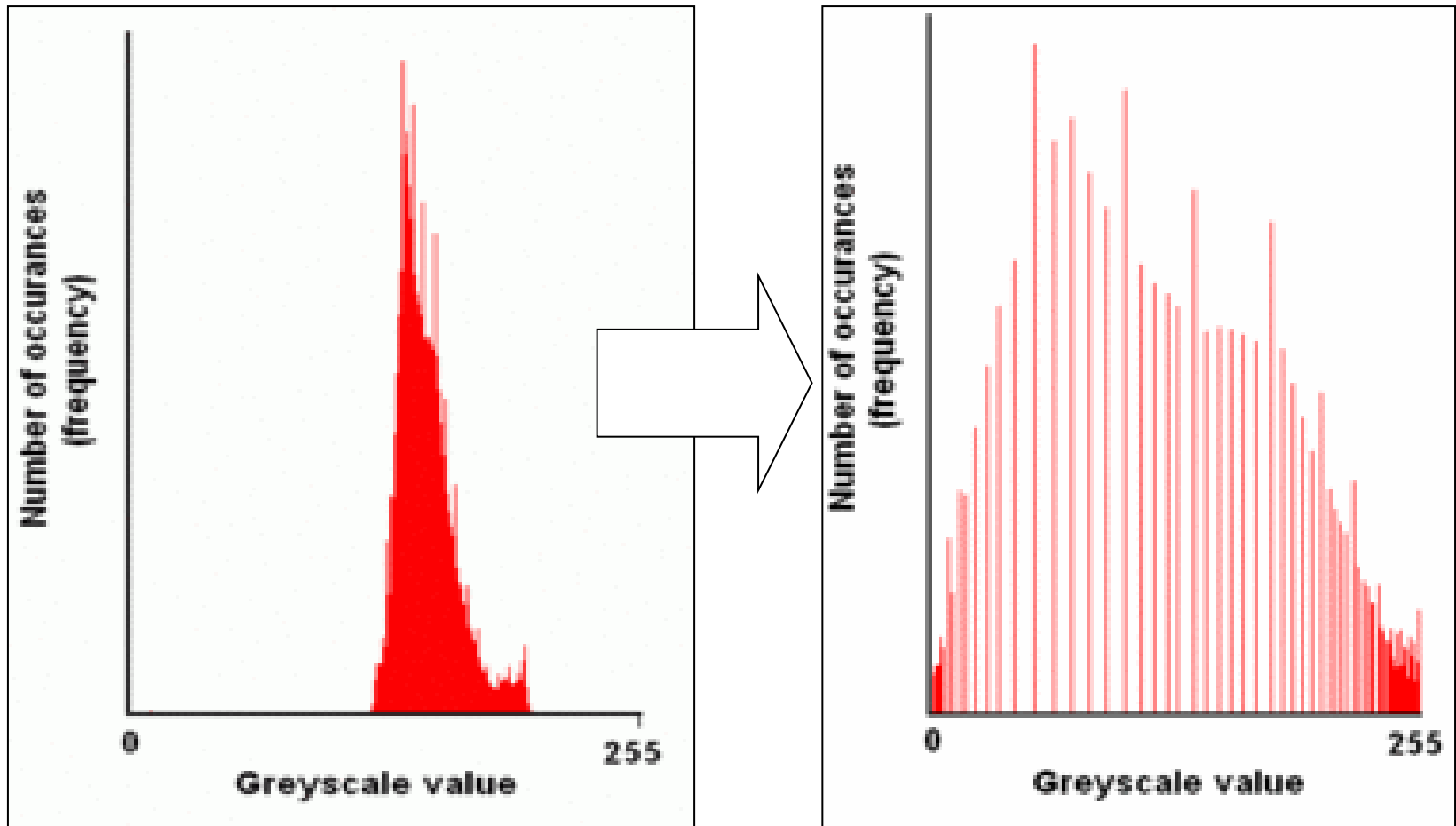
Topic: Neighborhoods and Connectivity

- Dynamic Range Manipulation

- Neighborhoods and Connectivity

- Image Arithmetic

- Example: Background Subtraction

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?

(x,y-1)

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

(x,y+1)

8-Neighbors

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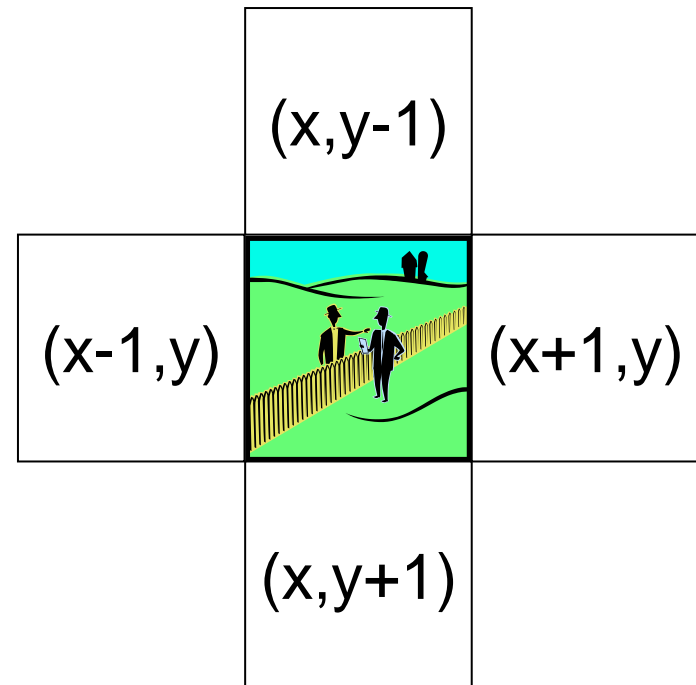 - $(x+1,y+1)$, $(x+1,y-1)$, $(x-1,y+1)$, $(x-1,y-1)$
  - $N_D(p)$: Diagonal set of neighbors
- $N_8(p) = N_4(p)+N_D(p)$
- Limitations?

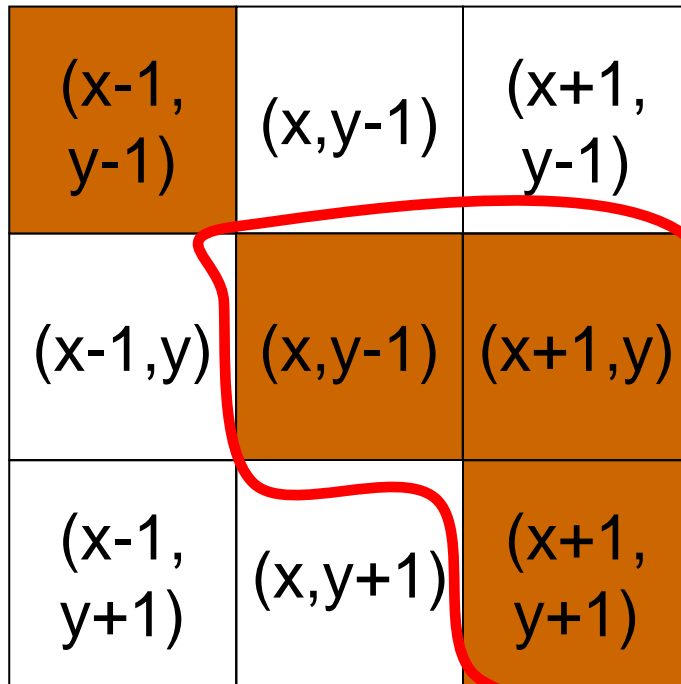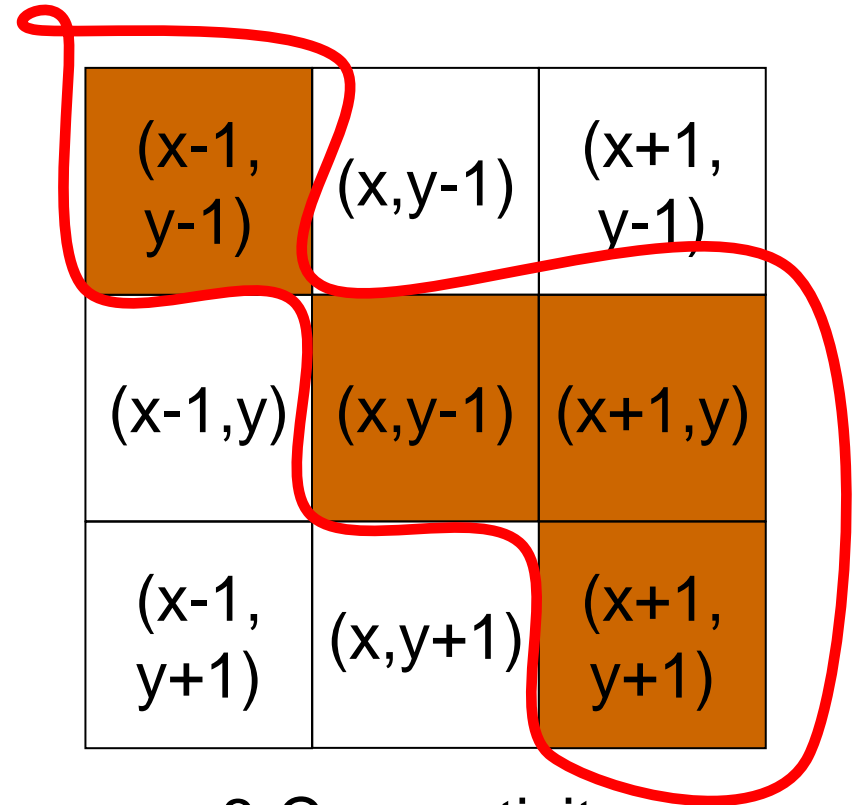| $(x-1, y-1)$	$(x,y-1)$	$(x+1, y-1)$
$(x-1,y)$		$(x+1,y)$
$(x-1, y+1)$	$(x,y+1)$	$(x+1, y+1)$
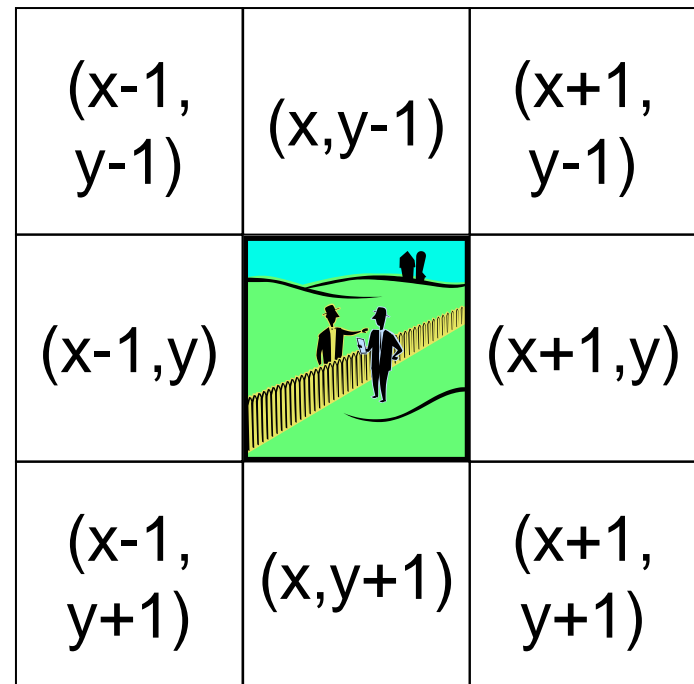
Connectivity

- 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

(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-Connectivity

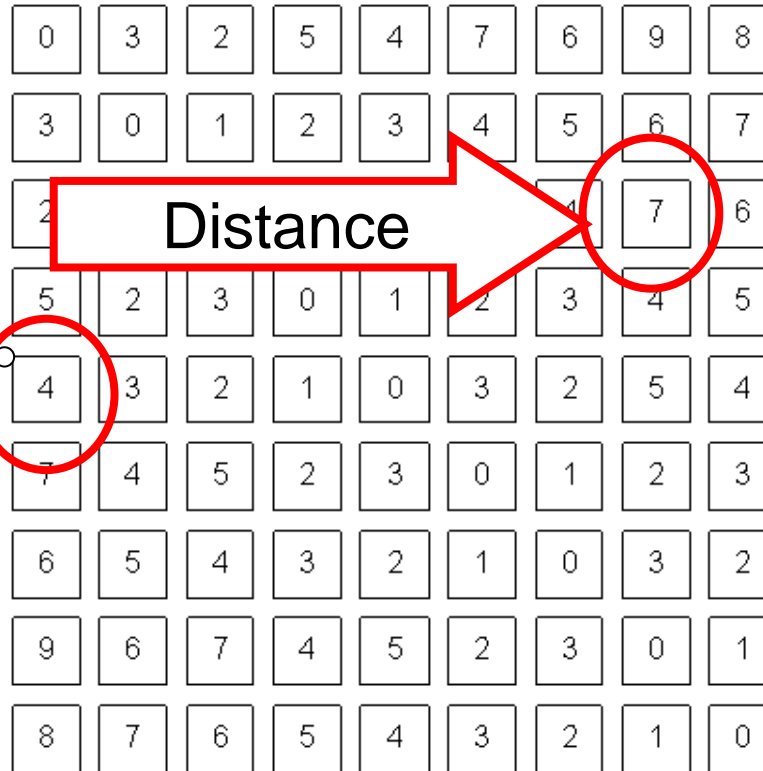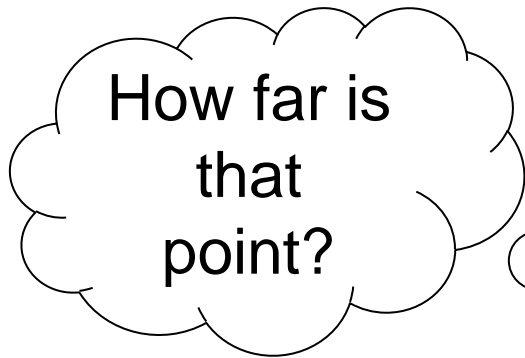|		
(x-1, y-1)	(x,y-1)	(x+1, y-1)
(x-1,y)	(x,y-1)	(x+1,y)
(x-1, y+1)	(x,y+1)	(x+1, y+1)

8-Connectivity

Distances

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 $D_4 \le 2$ from p

```
        2
     2  1  2
  2  1  0  1  2        D₄ = 1 are the 4-neighbors of p
     2  1  2
        2
```

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          D₈ = 1 are the 8-neighbors of p
2  1  1  1  2
2  2  2  2  2
```
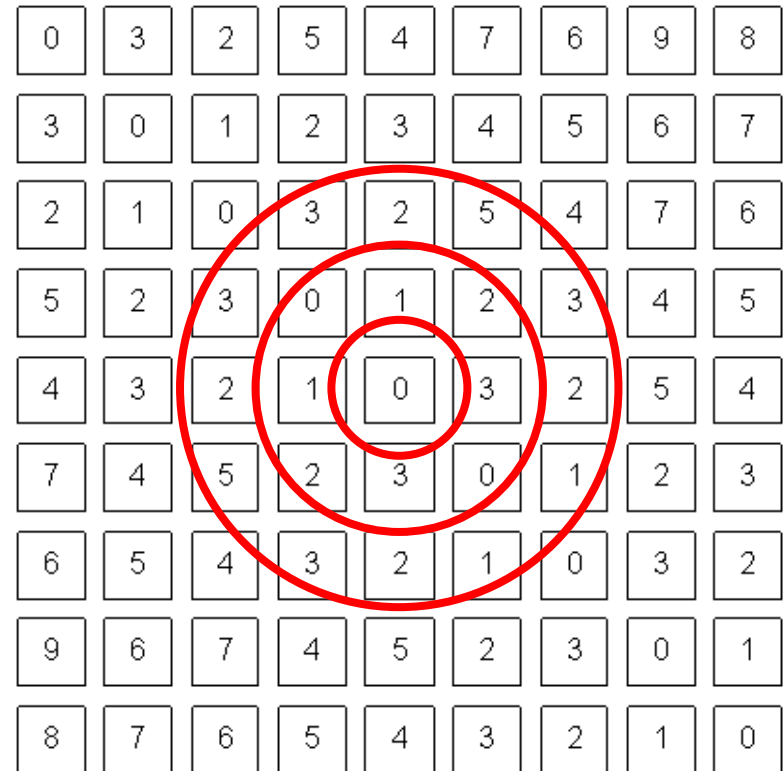
$D_8 = 1$ are the 8-neighbors of p

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
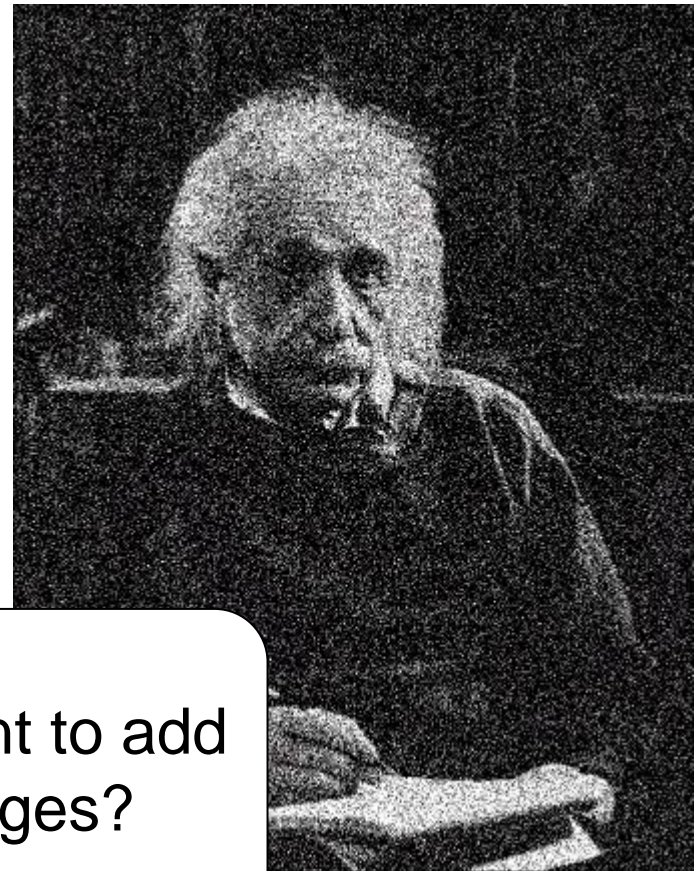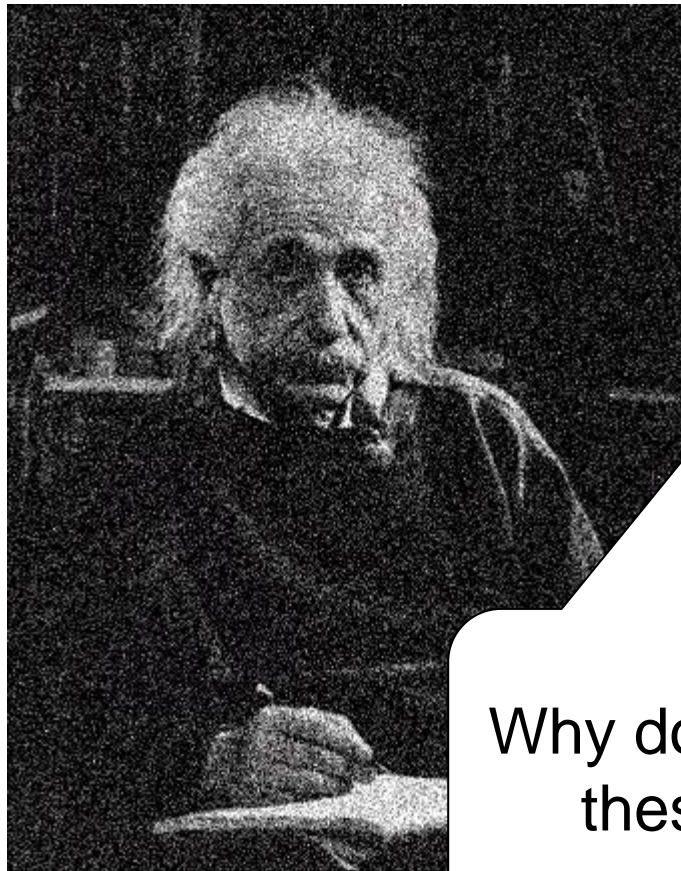- Image Arithmetic
- Example: Background Subtraction

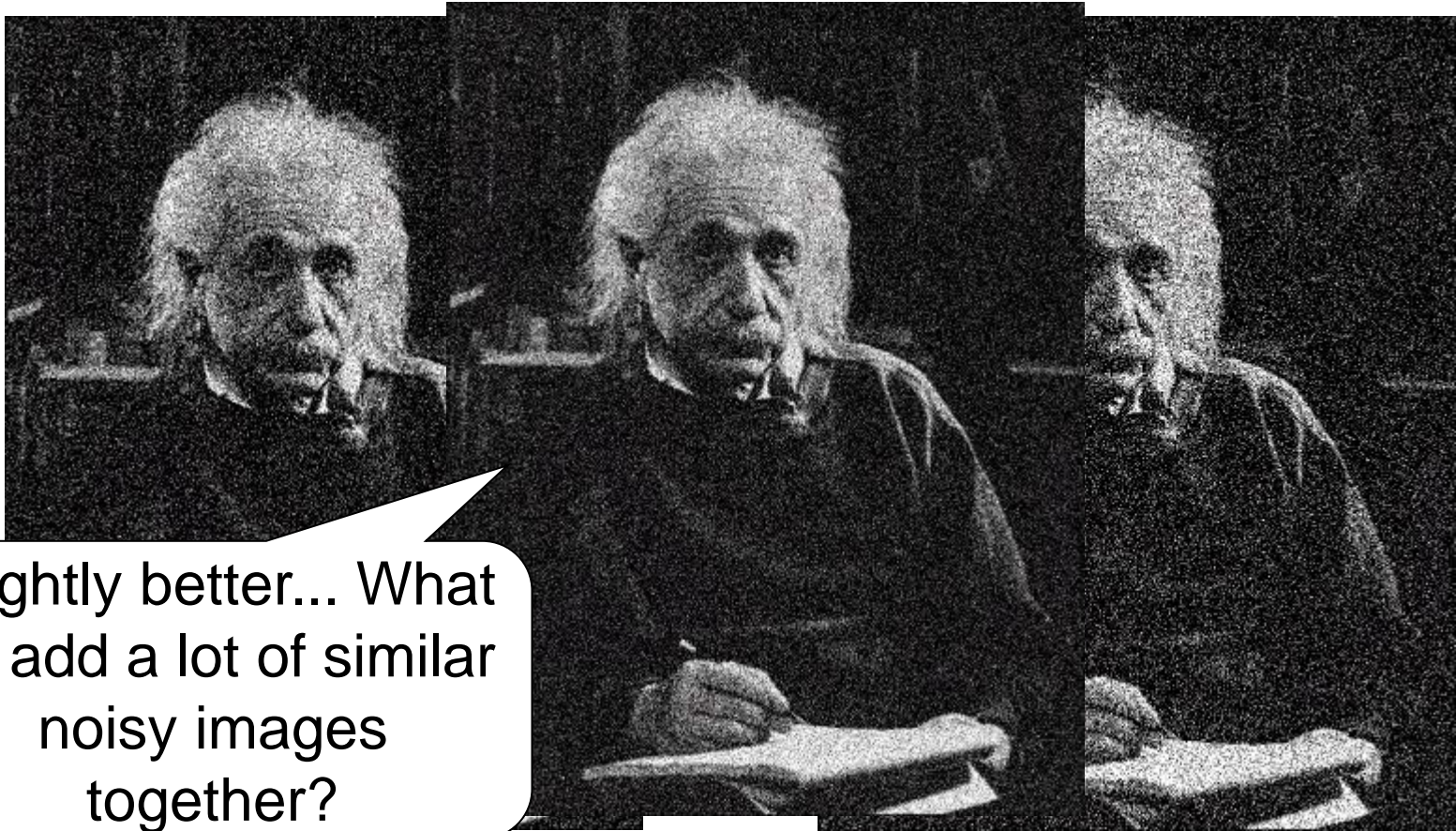# Arithmetic operations between images

Arithmetic operations between images
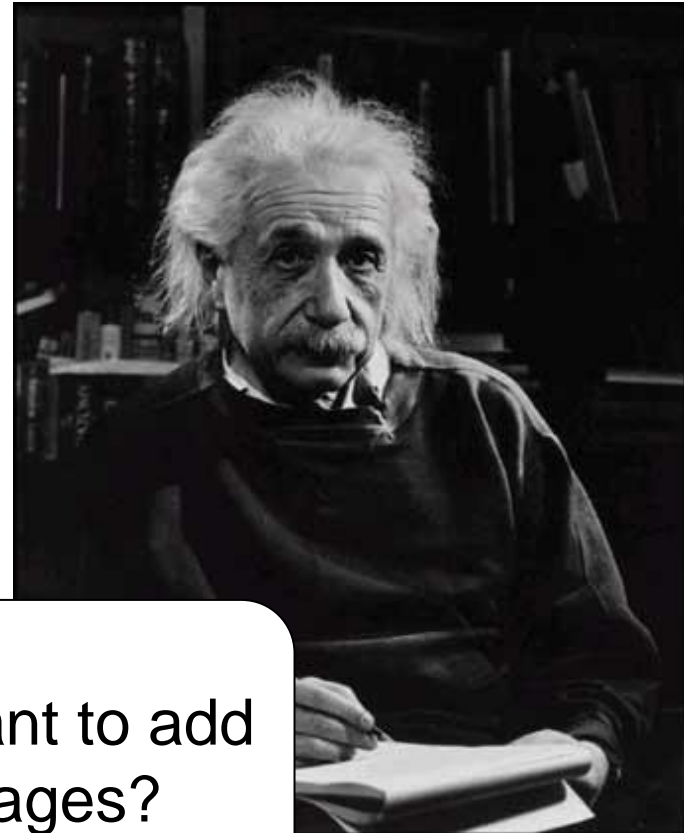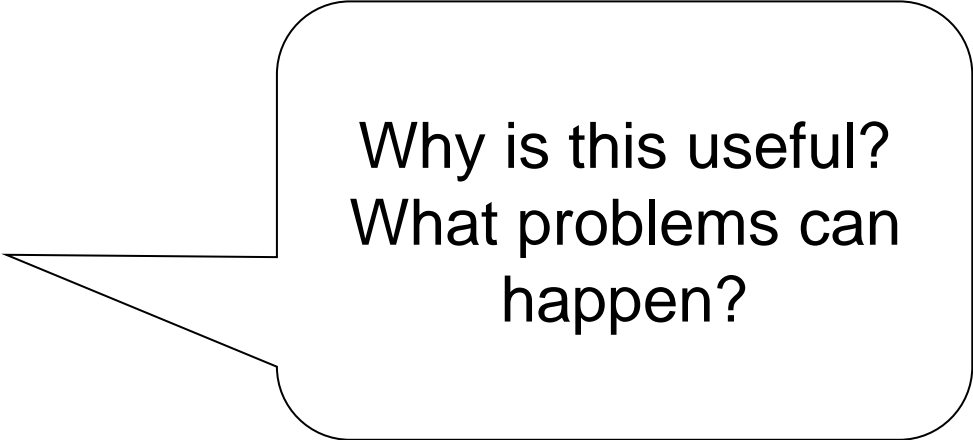

Why do I want to add these images?

Arithmetic operations between images

Slightly better... What if I add a lot of similar noisy images together?
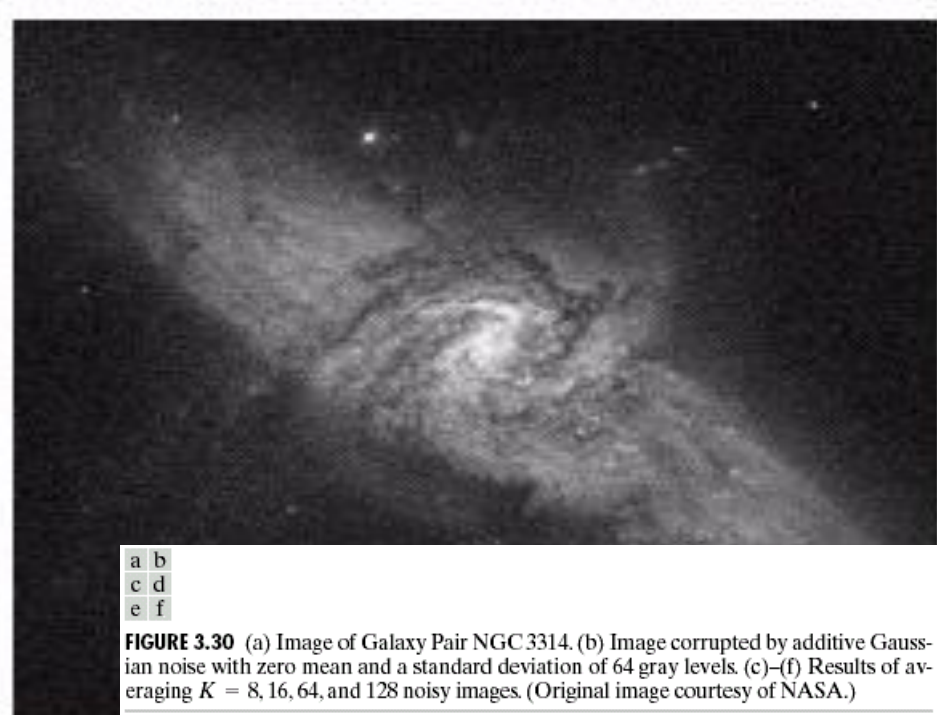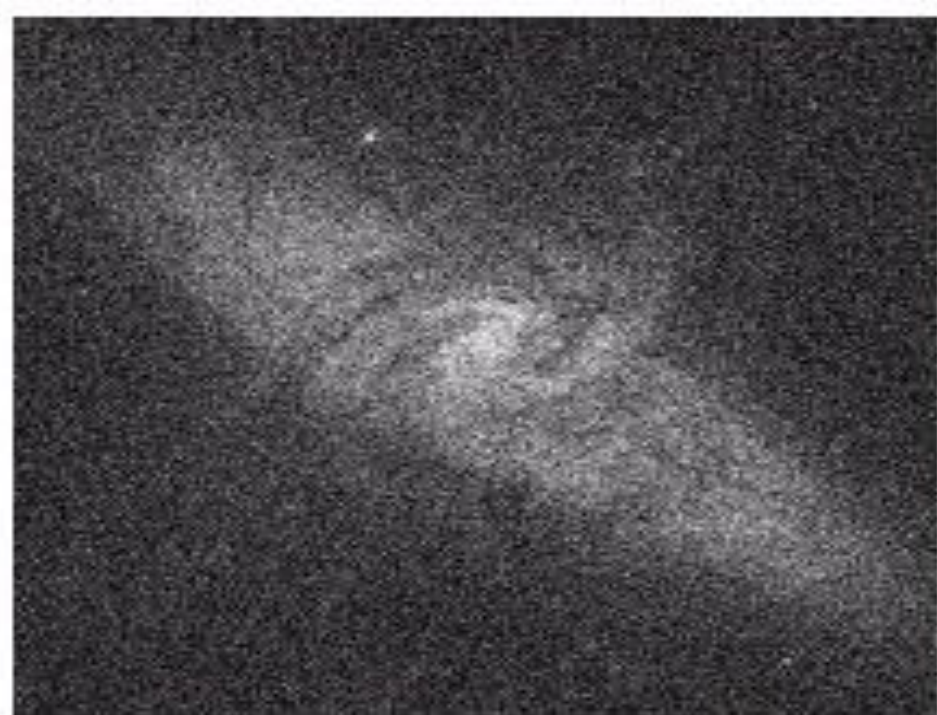
Image Arithmetic

- 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?
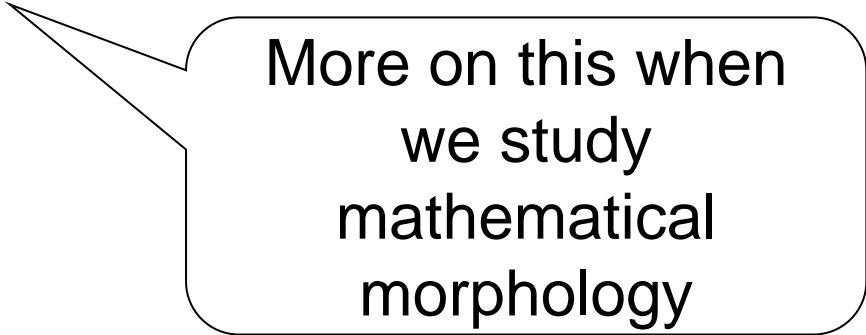
U. PORTO FC

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

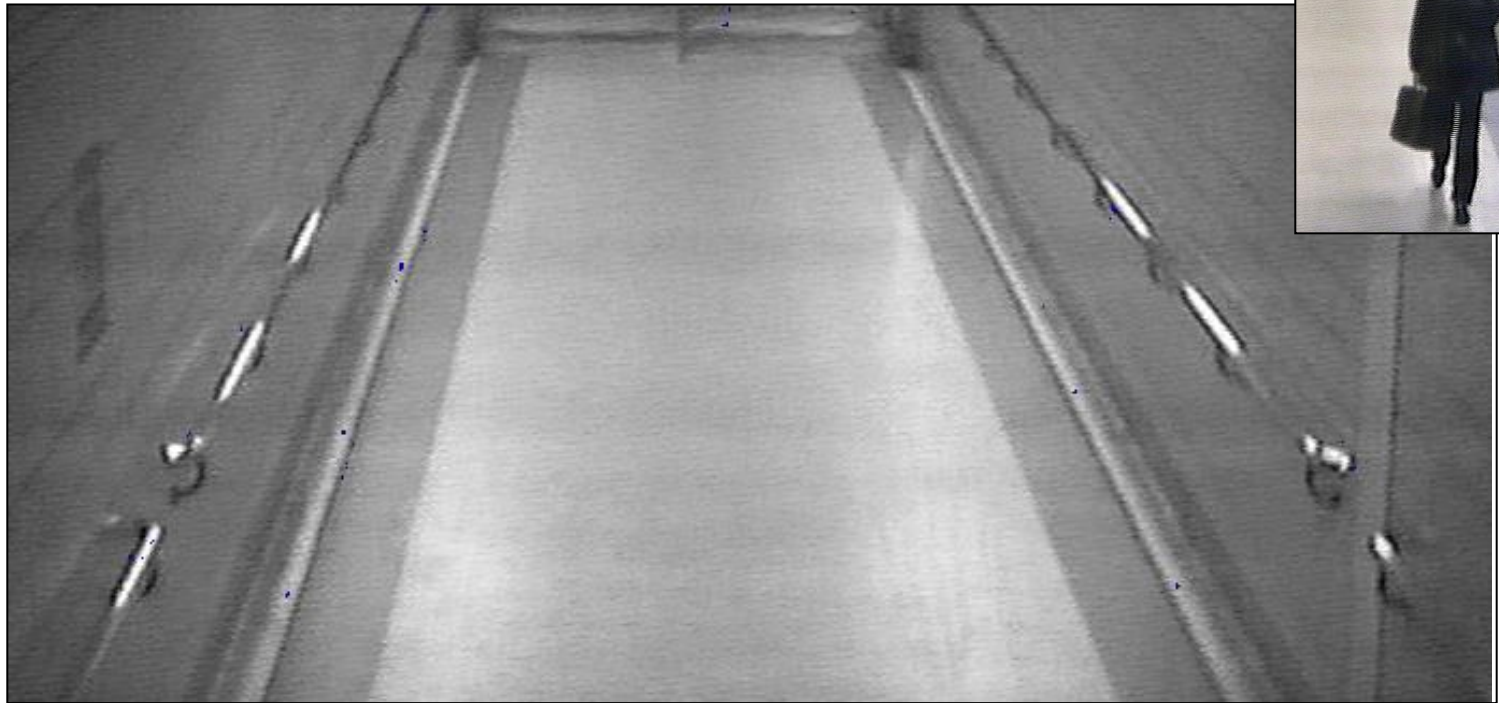- Remember: We can only see numbers!

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.

U. PORTO FC

Resources

- Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2011
  - Chapter 3 – "Image Processing"