VC 19/20 – TP5
Single Pixel Manipulation

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos

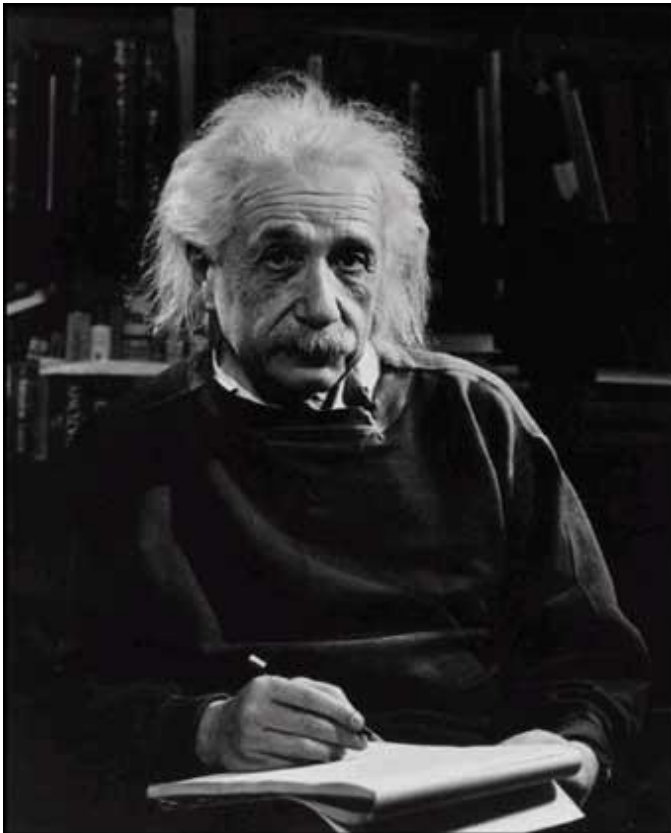*Miguel Tavares Coimbra*

Outline

- Dynamic Range Manipulation

- Neighborhoods and Connectivity

- Image Arithmetic

- Example: Background Subtraction
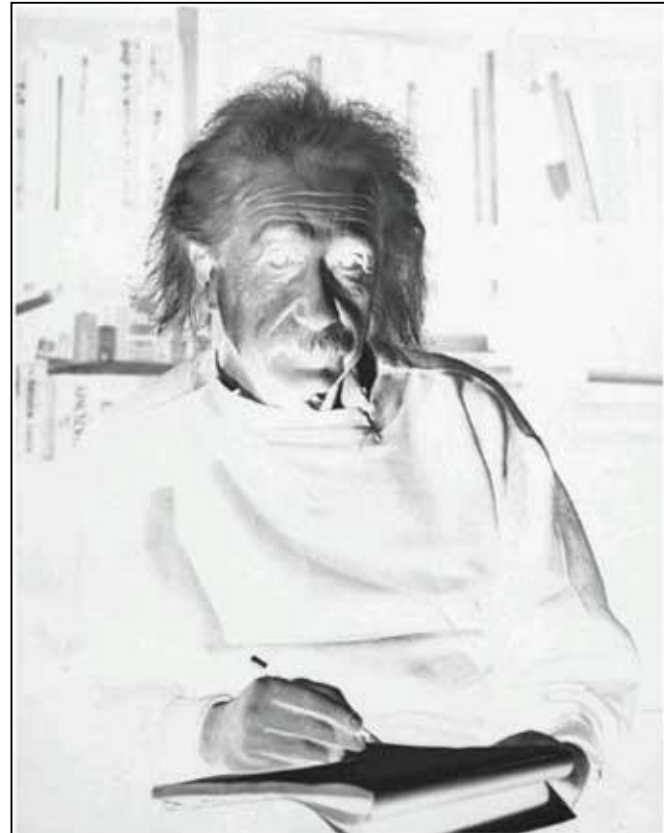
Topic: Dynamic Range Manipulation

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

Manipulation

What I see

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

Digital Images

To change this...

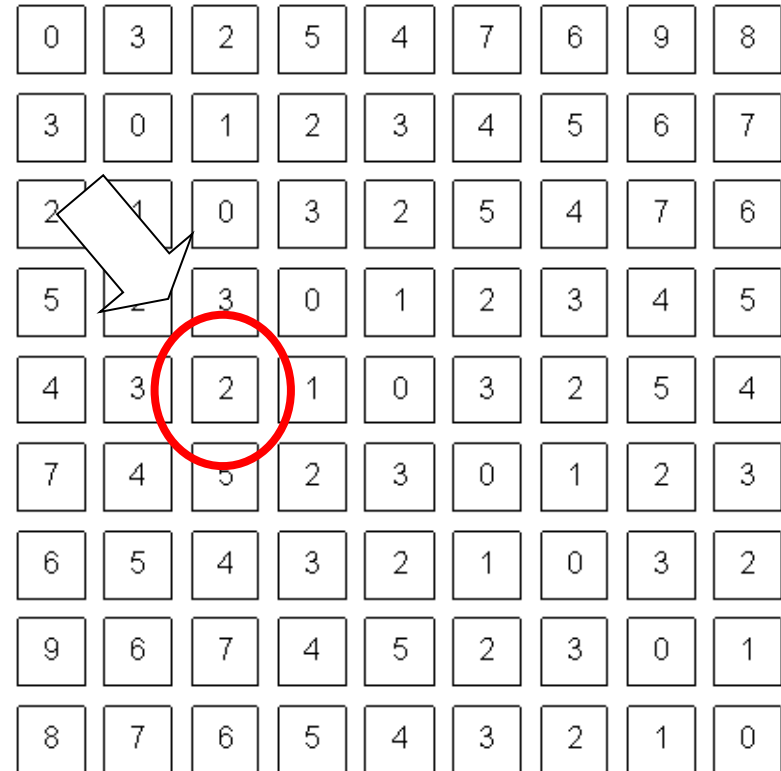I need to change this!

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.

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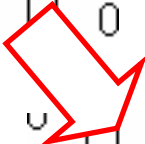
Image Domain

- I am directly changing values of the image matrix.

$$g = T(f)$$

- Image Domain

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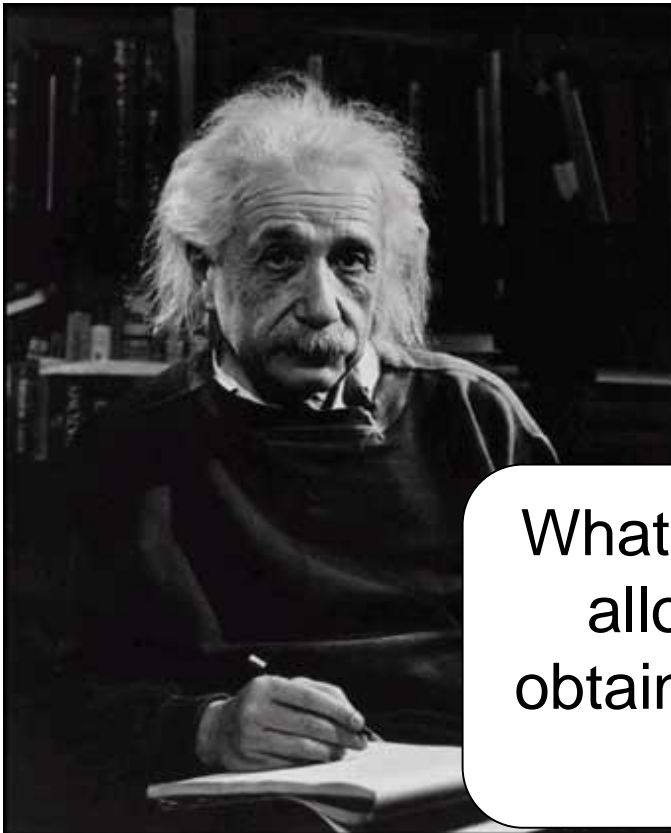
Image Negative

What I see

What I <u>want</u> to see
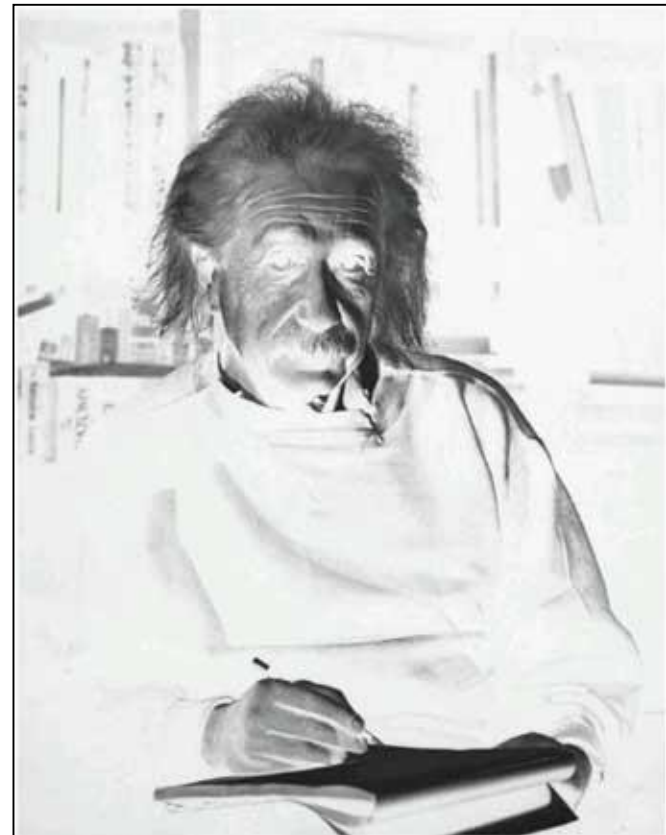
What operation T allows me to obtain this result?
g=T(f)

Image Negative

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

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

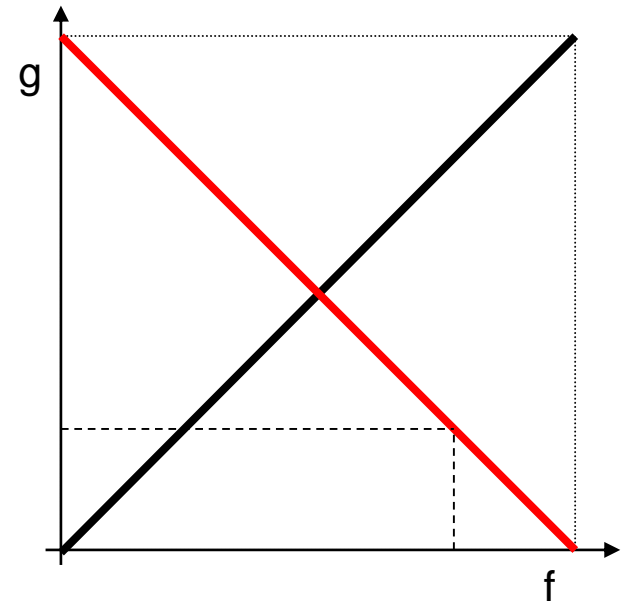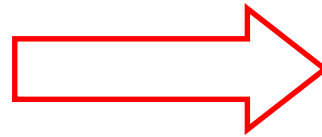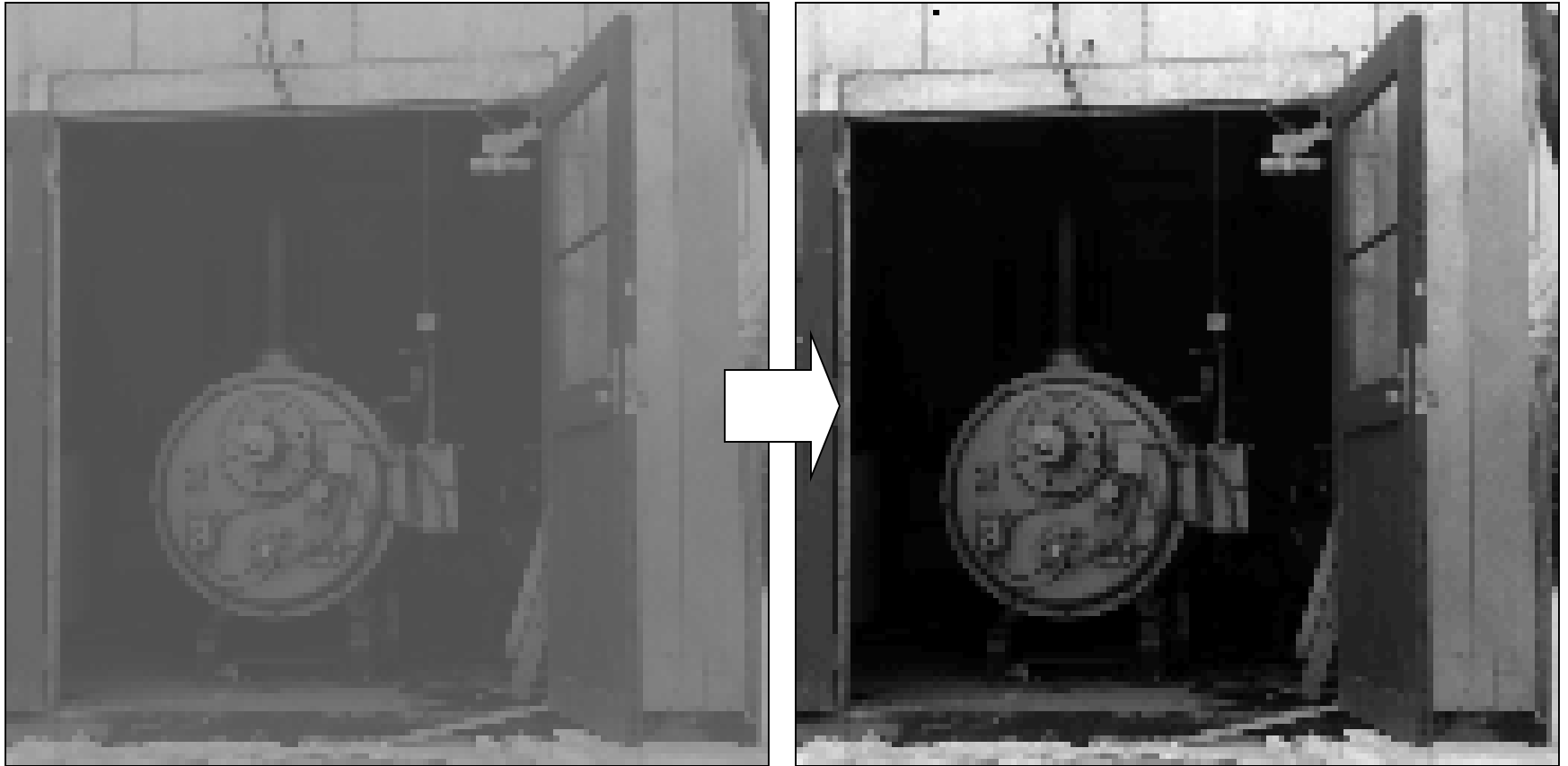$$g(x, y) = 255 - f(x, y)$$

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

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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.
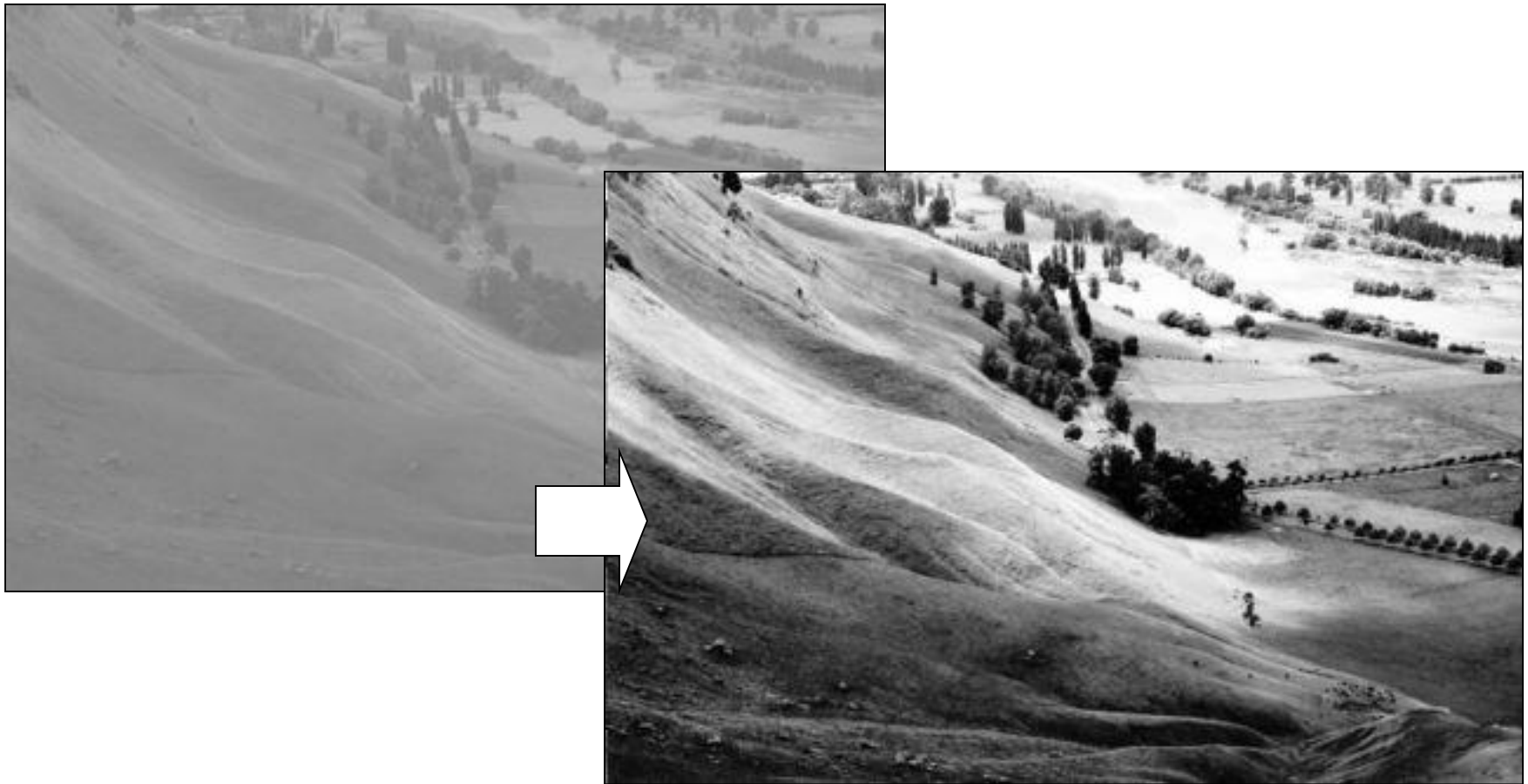
—— Normal

—— Inverted

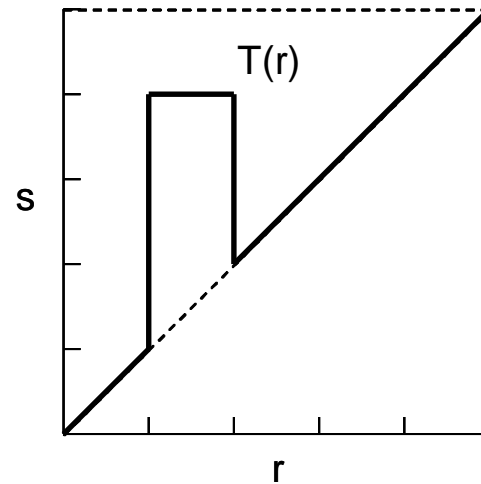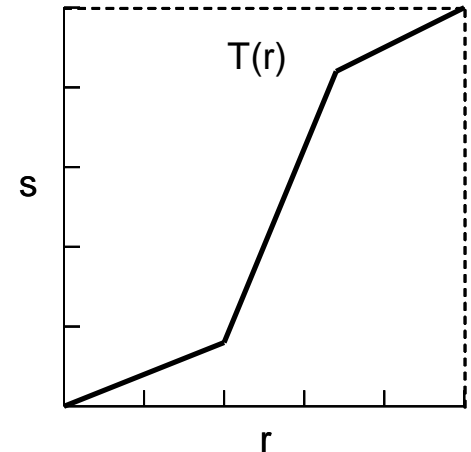# Why DRM?

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Why DRM?
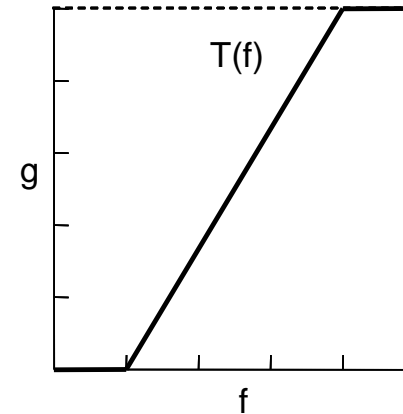
Other DRM functions

- ## 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.

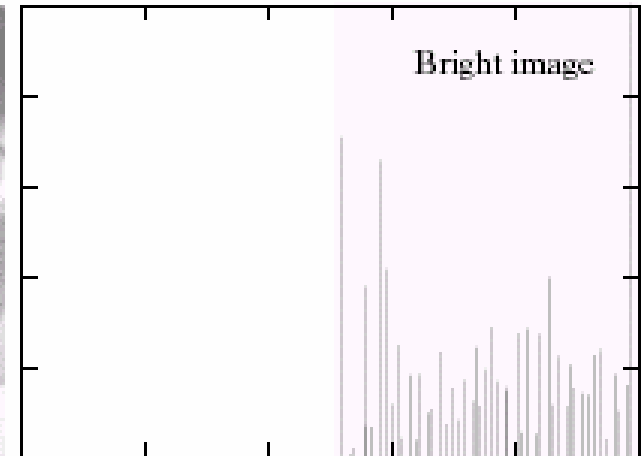$$g = 255 \frac{f - \min}{\max - \min}$$

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
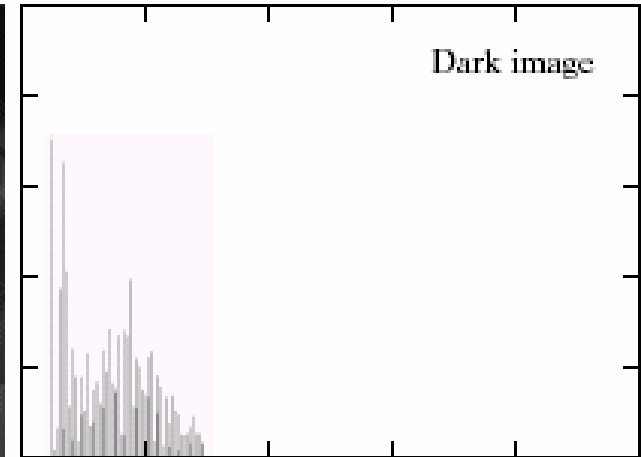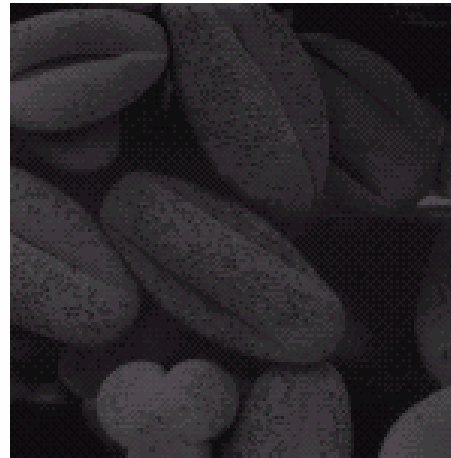
Dark image

Bright image
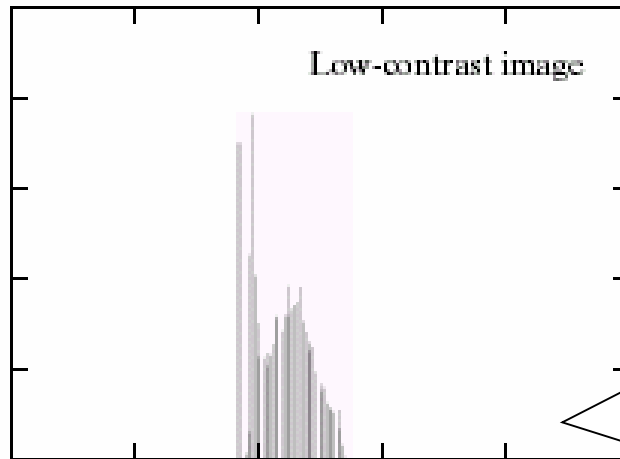
Types of Image Histograms
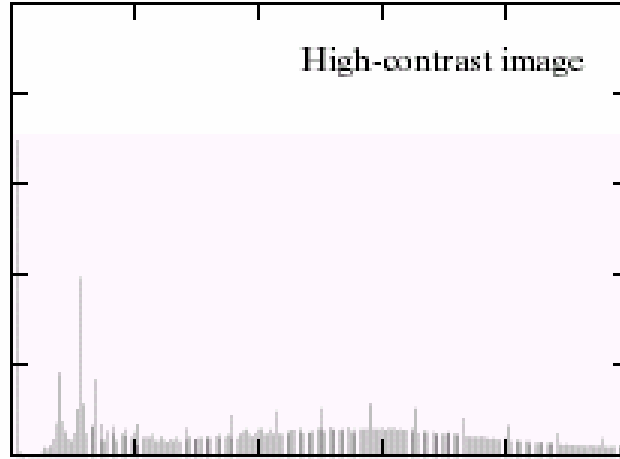
Histogram Equalization

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

- Objective:
  - Obtain a 'flat' histogram.
  - Enhance visual contrast.

- Digital histogram
  - Result is a 'flat-ish' histogram.
  - Why?
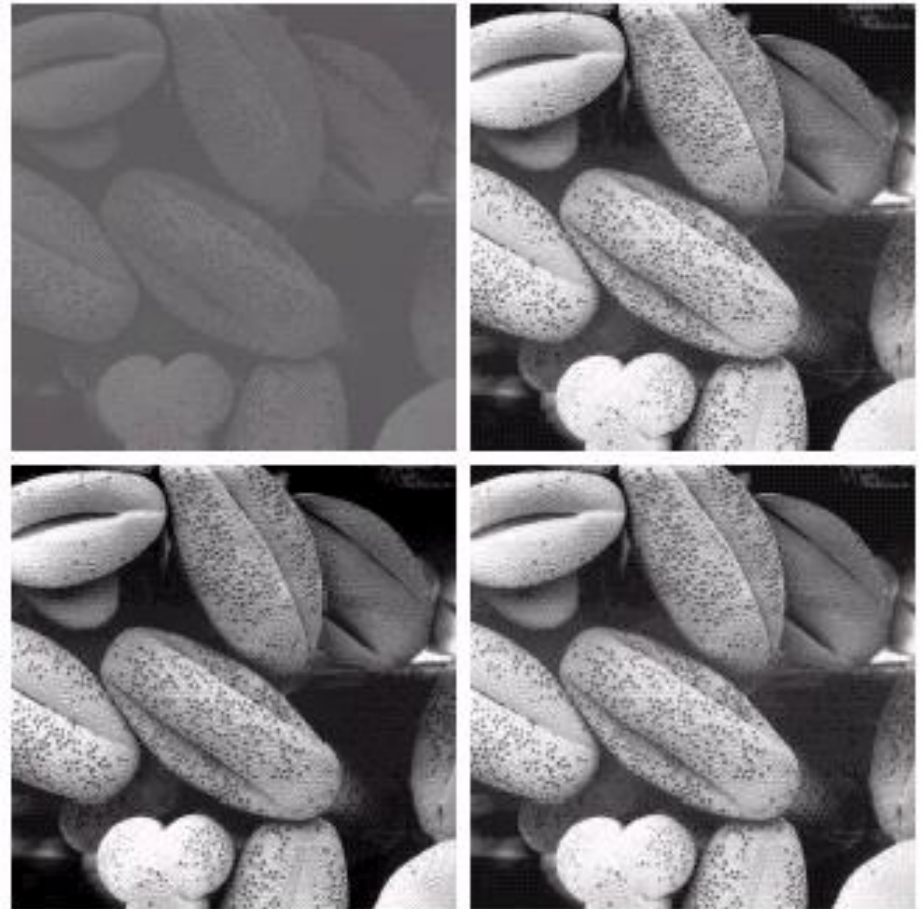
Histogram Equalization
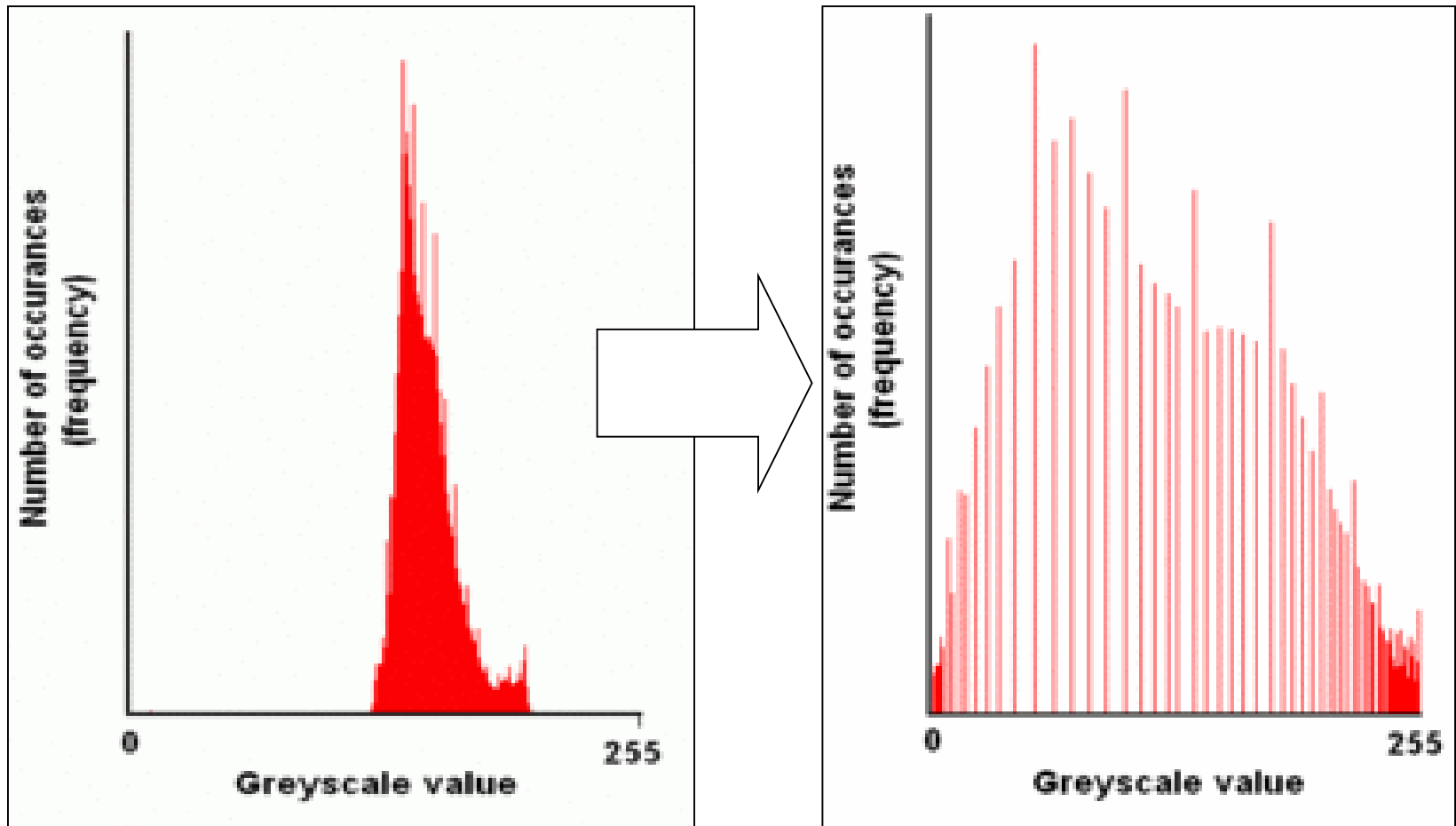
Topic: Neighborhoods and Connectivity

- Dynamic Range Manipulation

- Neighborhoods and Connectivity

- Image Arithmetic

- Example: Background Subtraction

Neighbors

Why do we care at all?
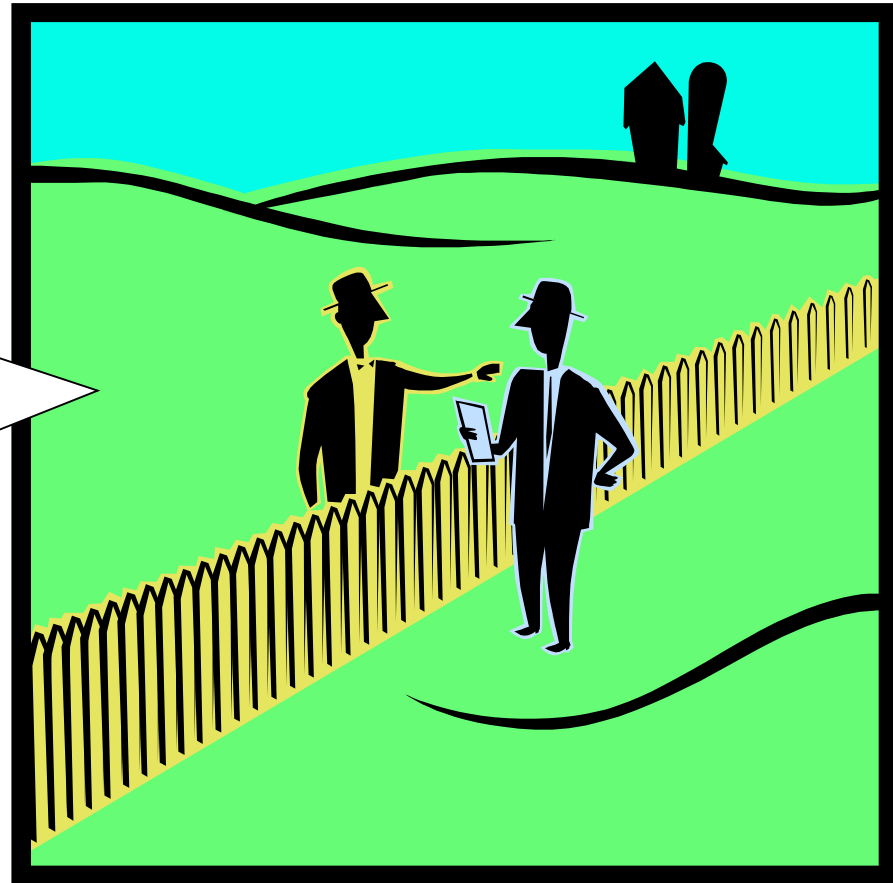
Digital Images
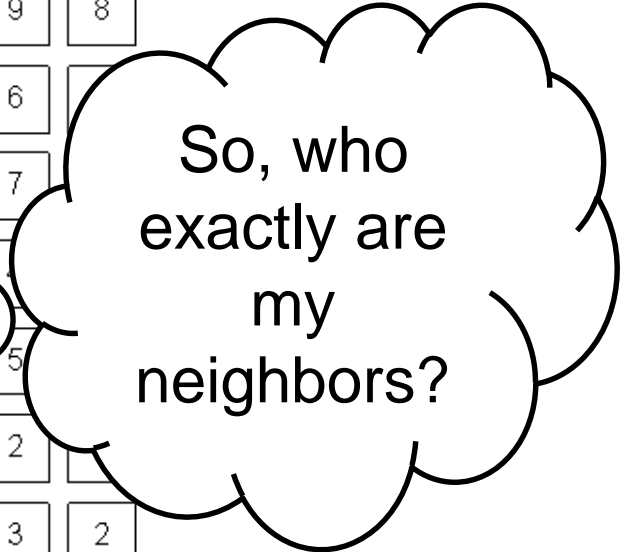
What a computer sees

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?

(x,y-1)

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

(x,y+1)
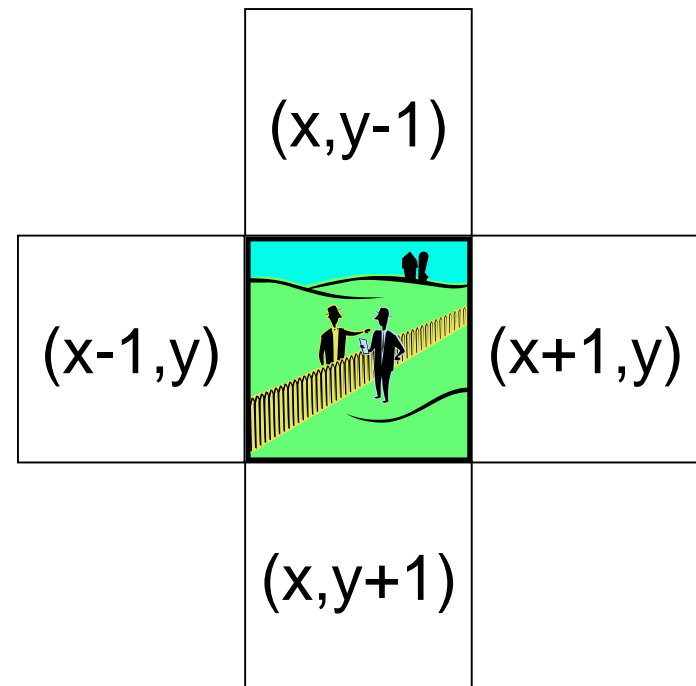
8-Neighbors

- 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?

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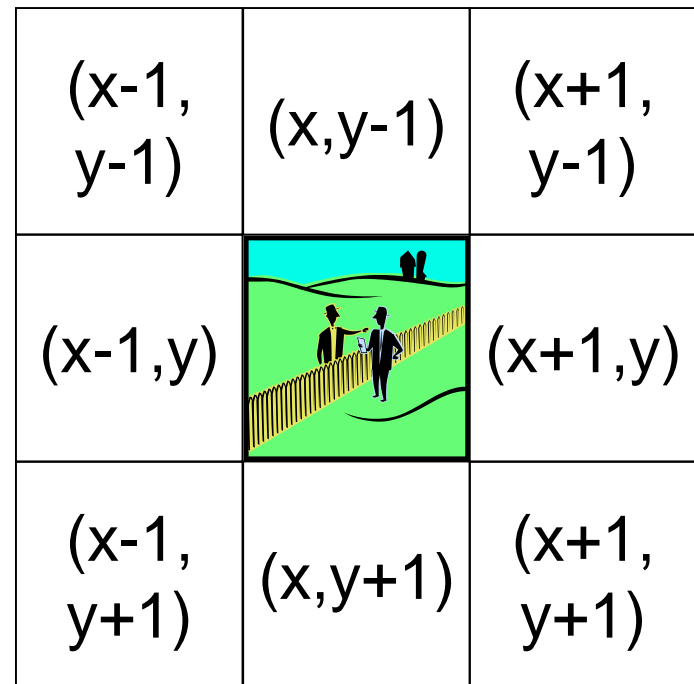
Connectivity

- 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)
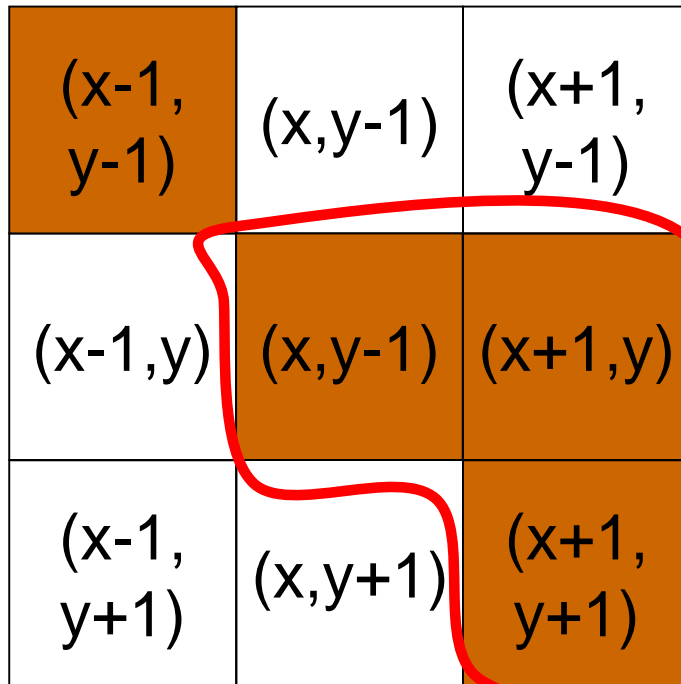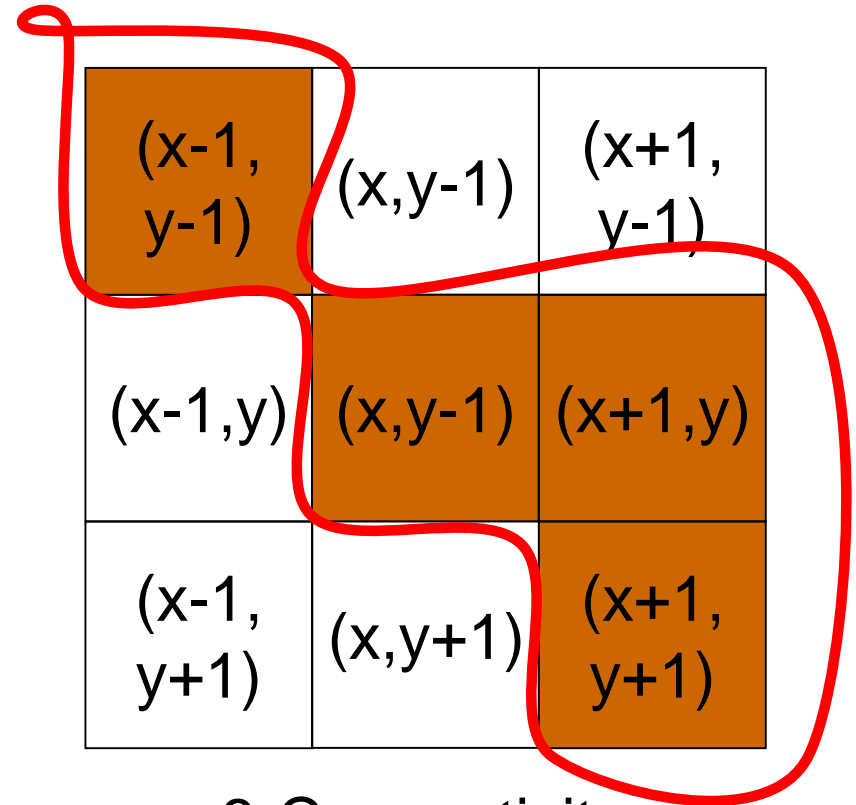
8-Connectivity

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 $D_4 \leq 2$ from p
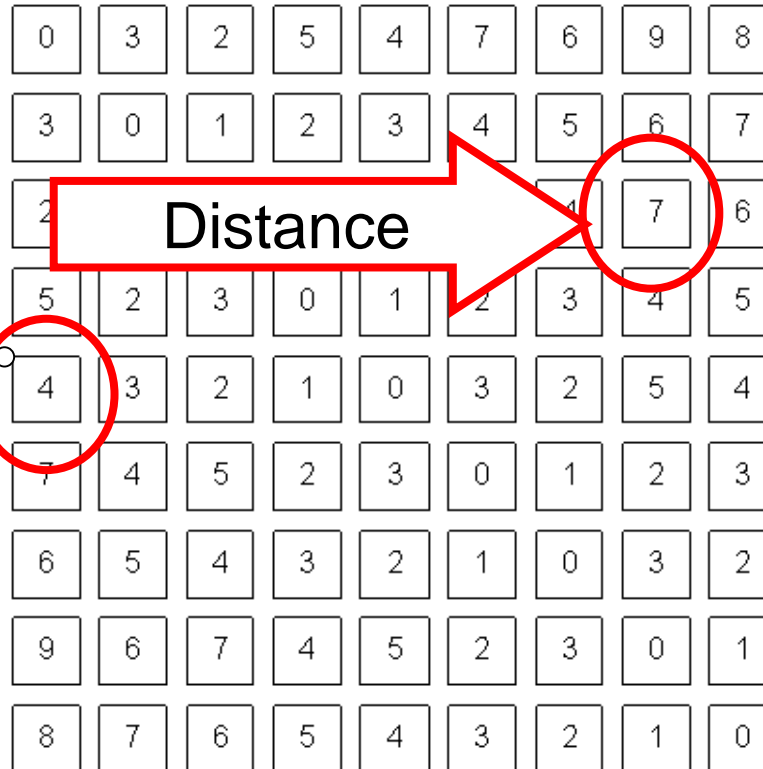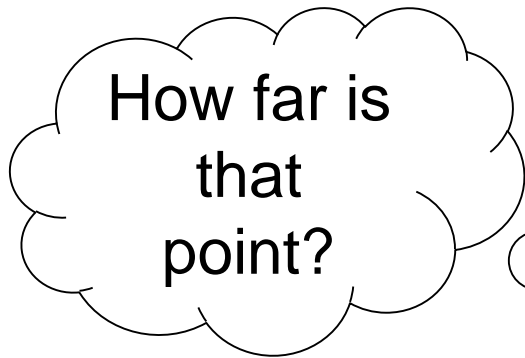
```
        2
      2 1 2
    2 1 0 1 2        D₄ = 1 are the 4-neighbors of p
      2 1 2
        2
```

$D_4 = 1$ 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$_8$≤2 from p

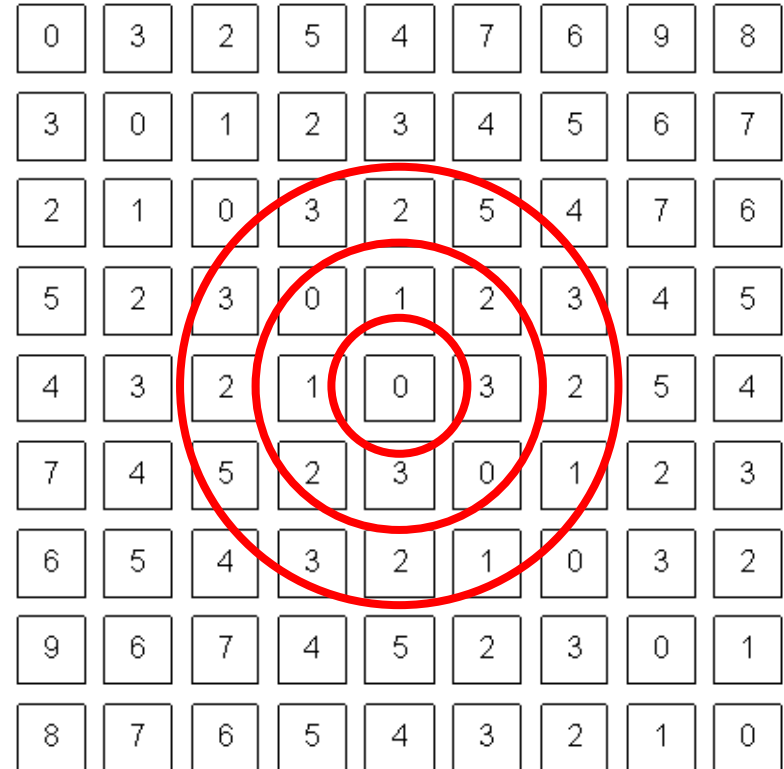 | 2 | 2 | 2 | 2 | 2 |
  |---|---|---|---|---|
  | 2 | 1 | 1 | 1 | 2 |
  | 2 | 1 | 0 | 1 | 2 |
  | 2 | 1 | 1 | 1 | 2 |
  | 2 | 2 | 2 | 2 | 2 |

  D$_8$ = 1 are the 8-neighbors of p

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Euclidean Distance

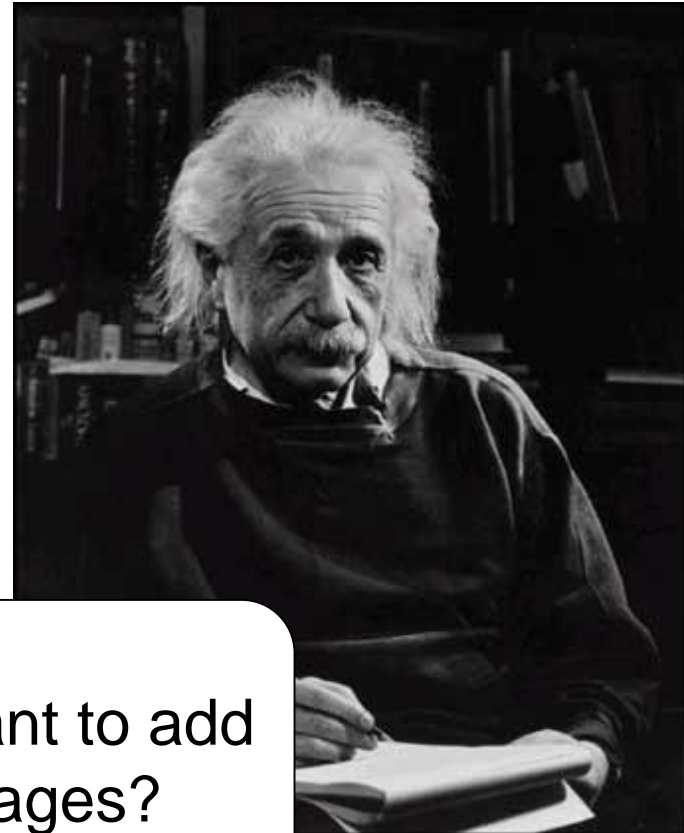- ## Euclidean distance:
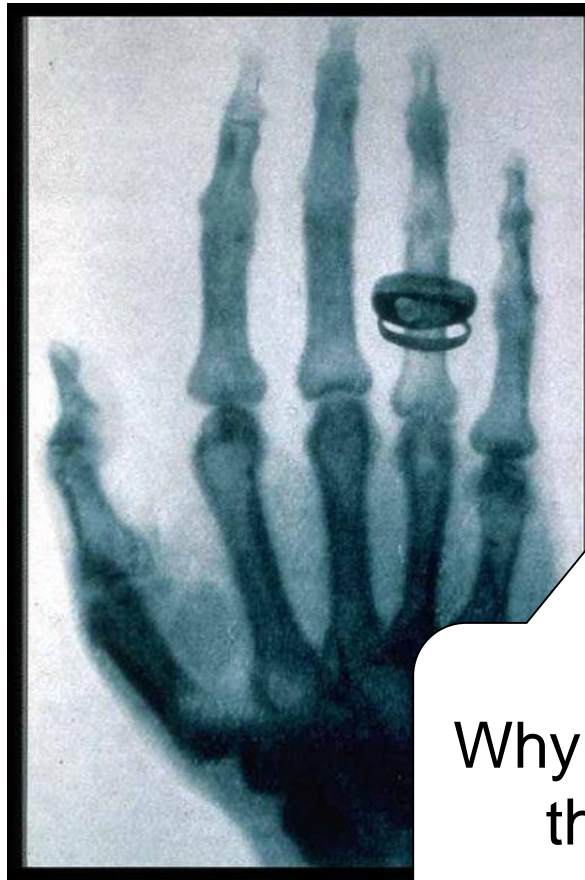
  - $D_e(p,q) = [(x-s)^2 + (y-t)^2]^{1/2}$

  - 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
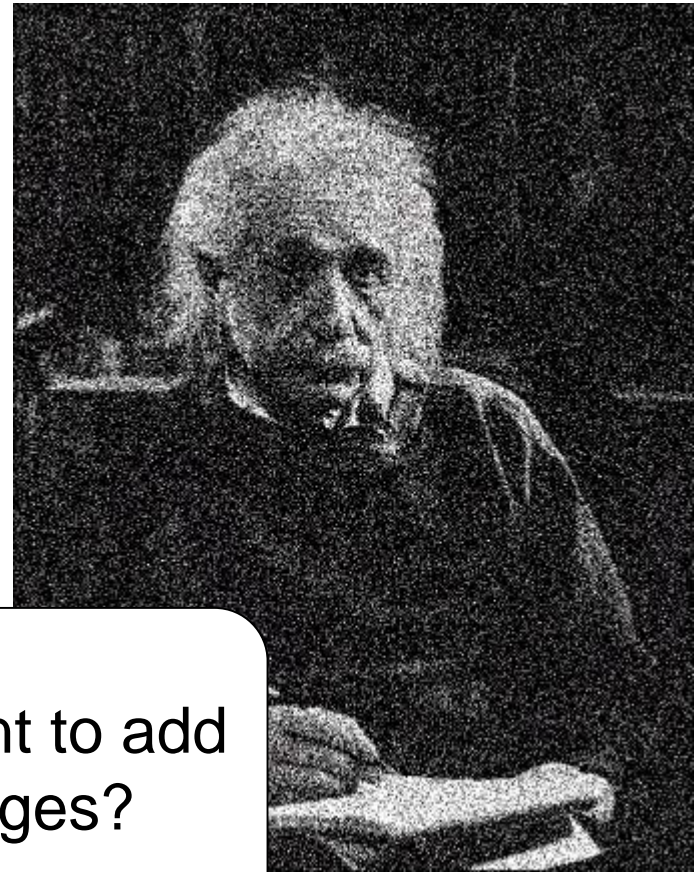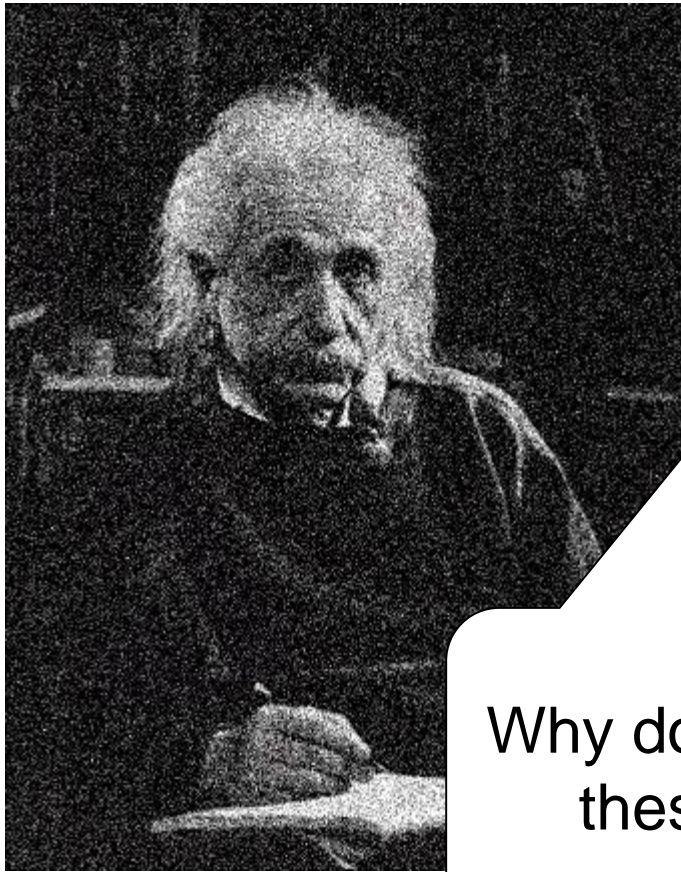- Example: Background Subtraction

Arithmetic operations between images

Why do I want to add these images?

Arithmetic operations between images

Why do I want to add these images?
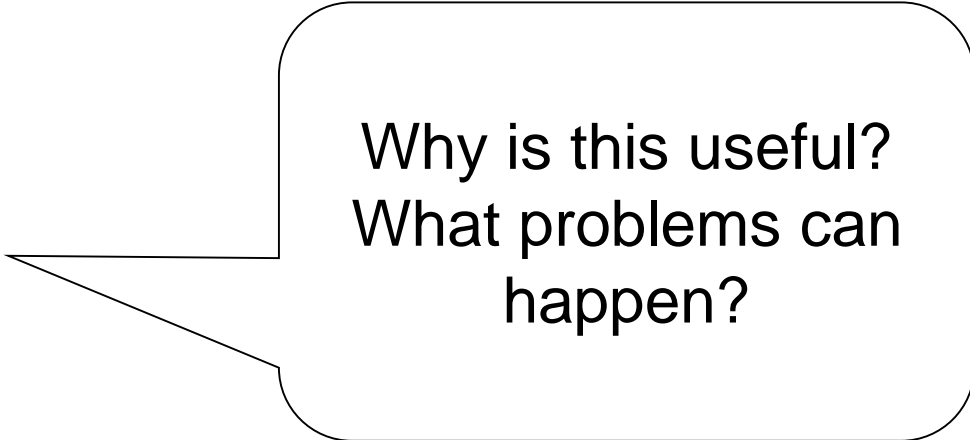
Arithmetic operations between images
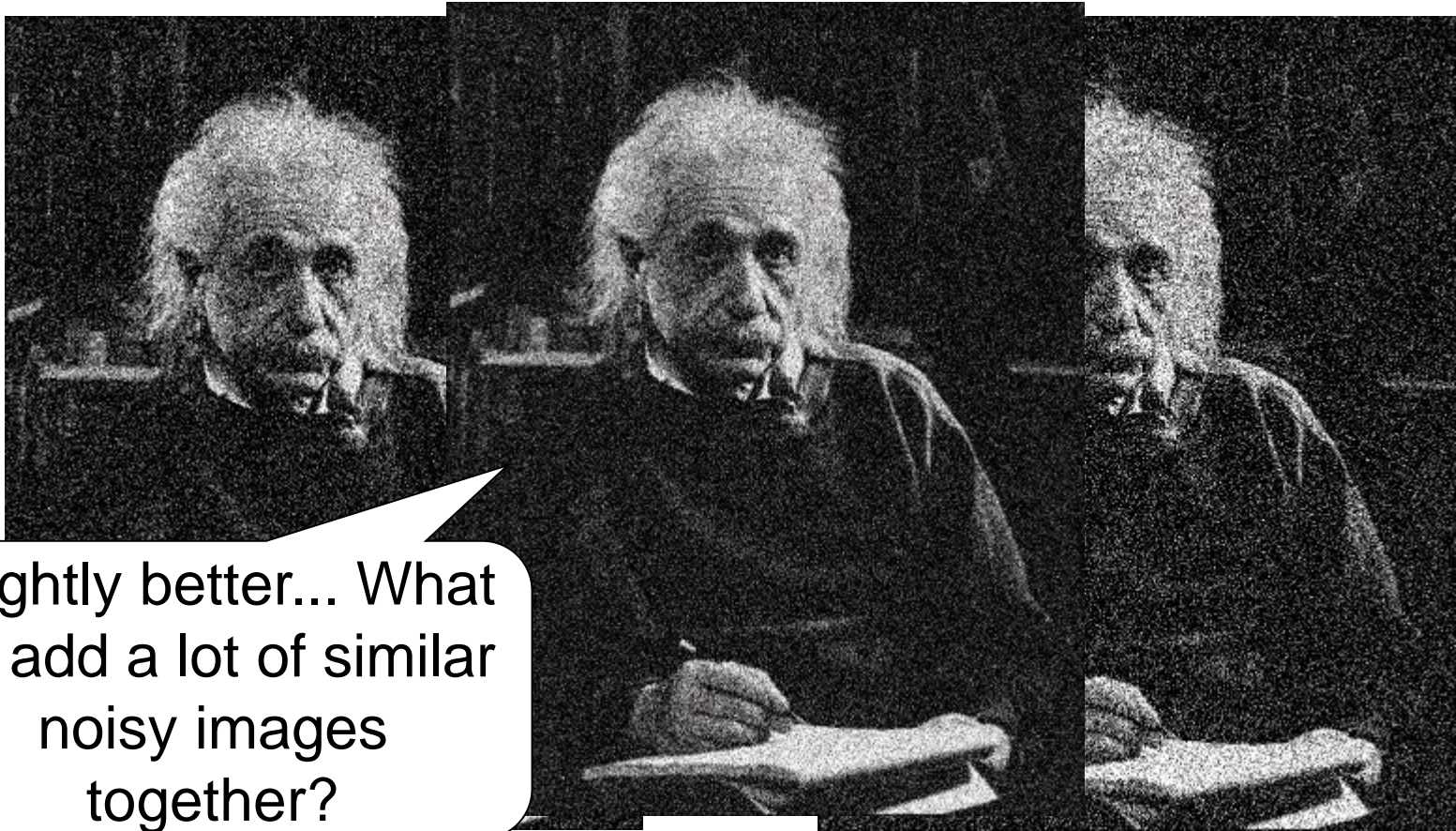
Slightly better... What if I add a lot of similar noisy images together?

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?

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Example

Image Addition

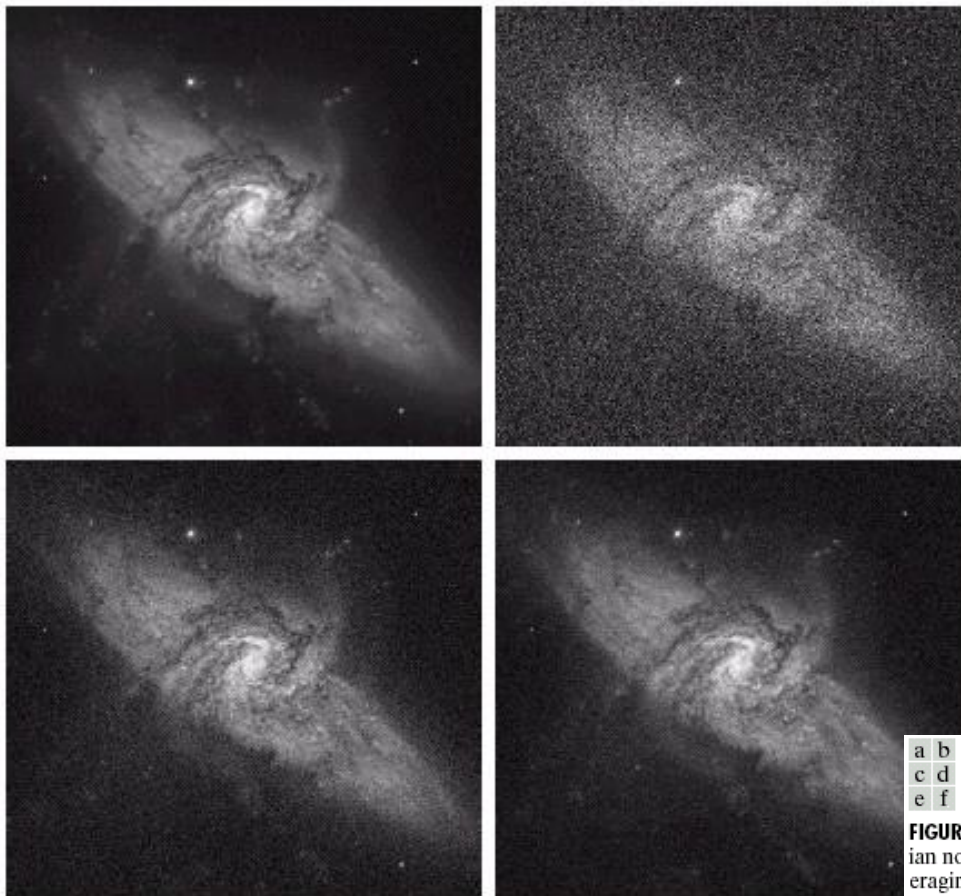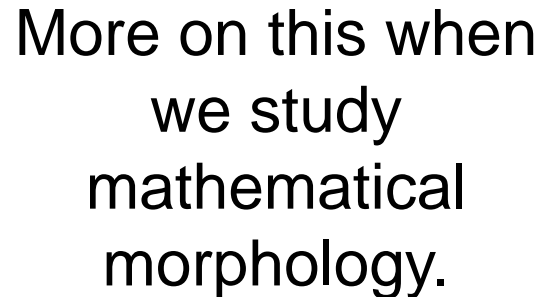FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64,$ and 128 noisy images. (Original image courtesy of NASA.)

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!

Is there a person here? Where?

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.