Computer Vision – TP5
Single Pixel Manipulation

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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
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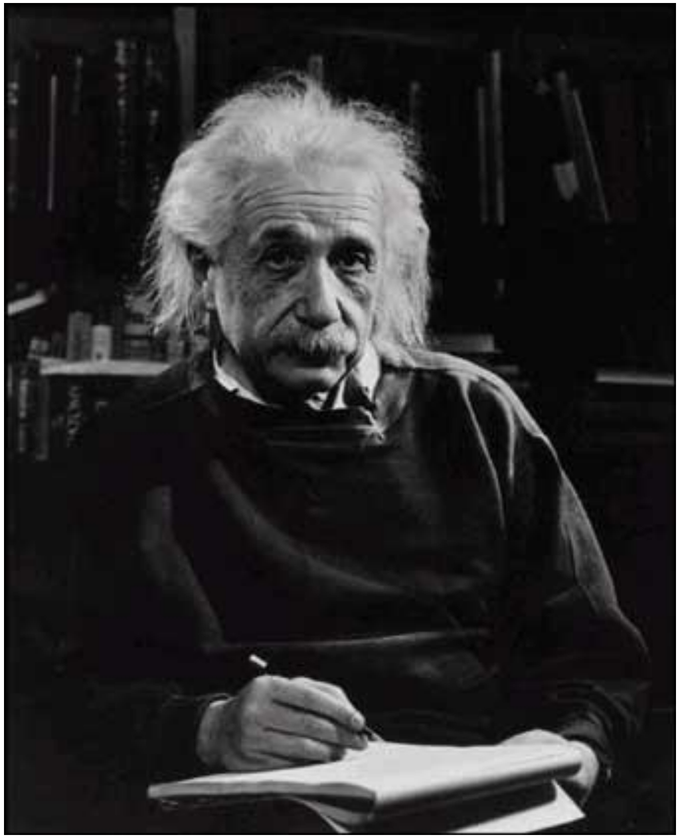
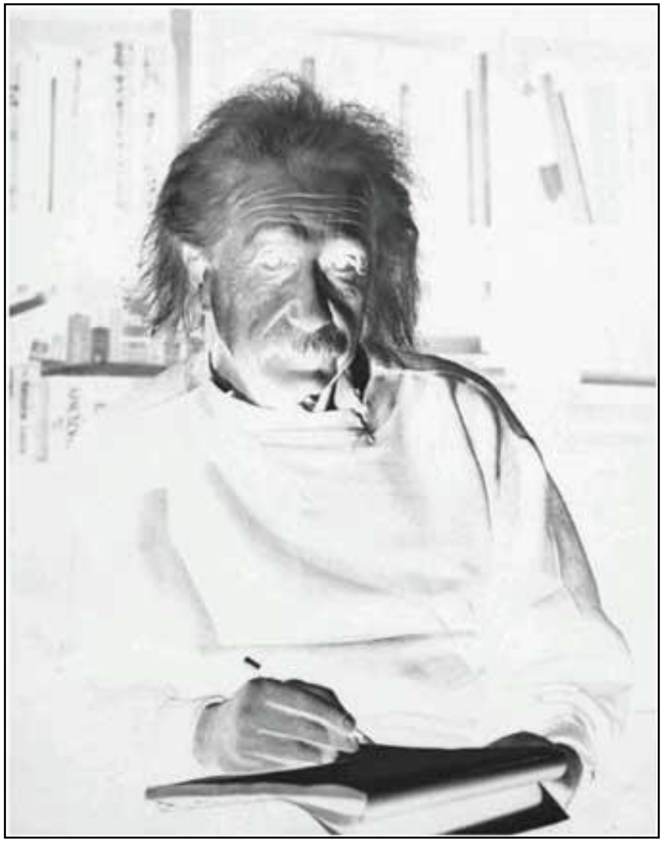
Manipulation

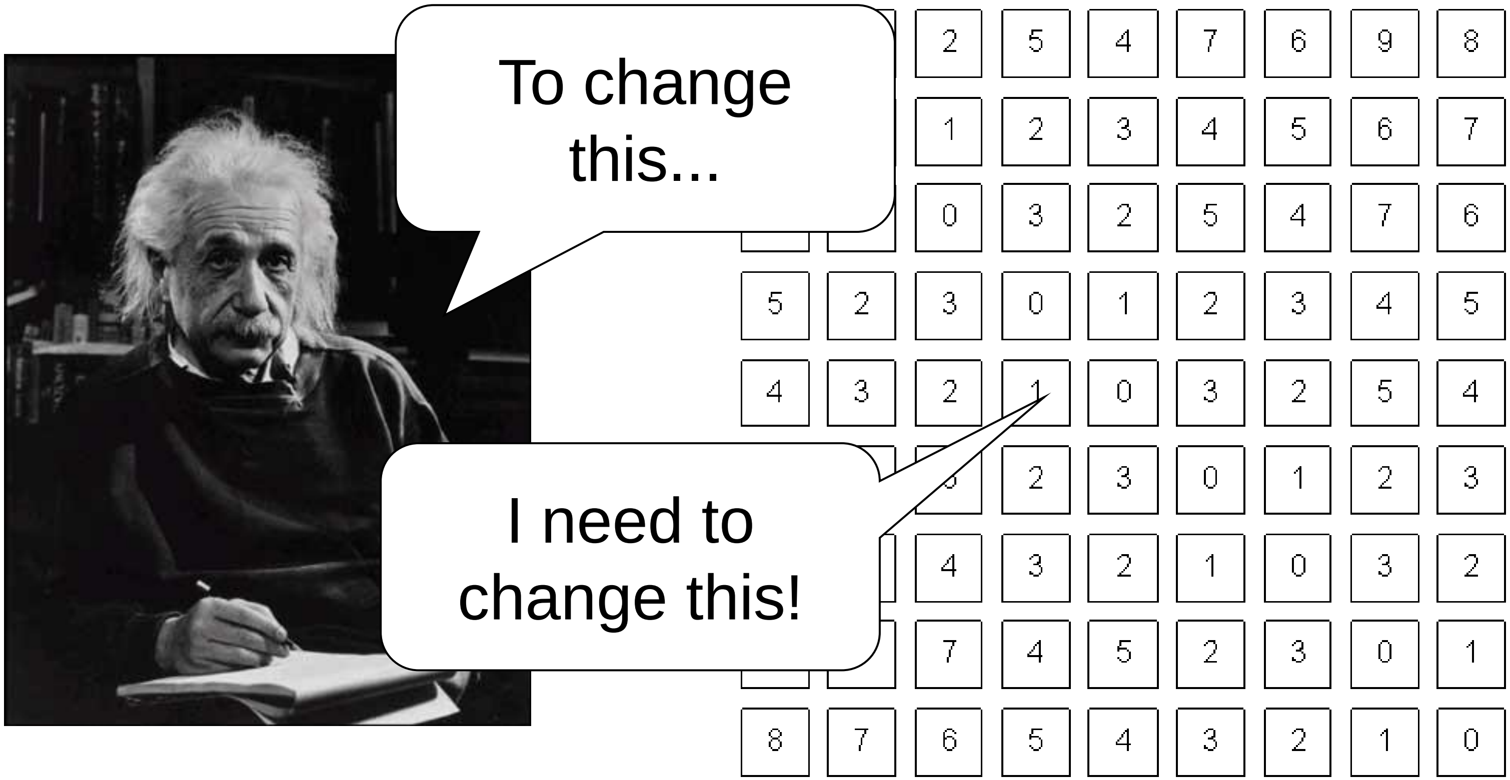


What I see



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

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.

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

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

Image Domain

- I am directly changing values of the image matrix.

$$g = T(f)$$

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

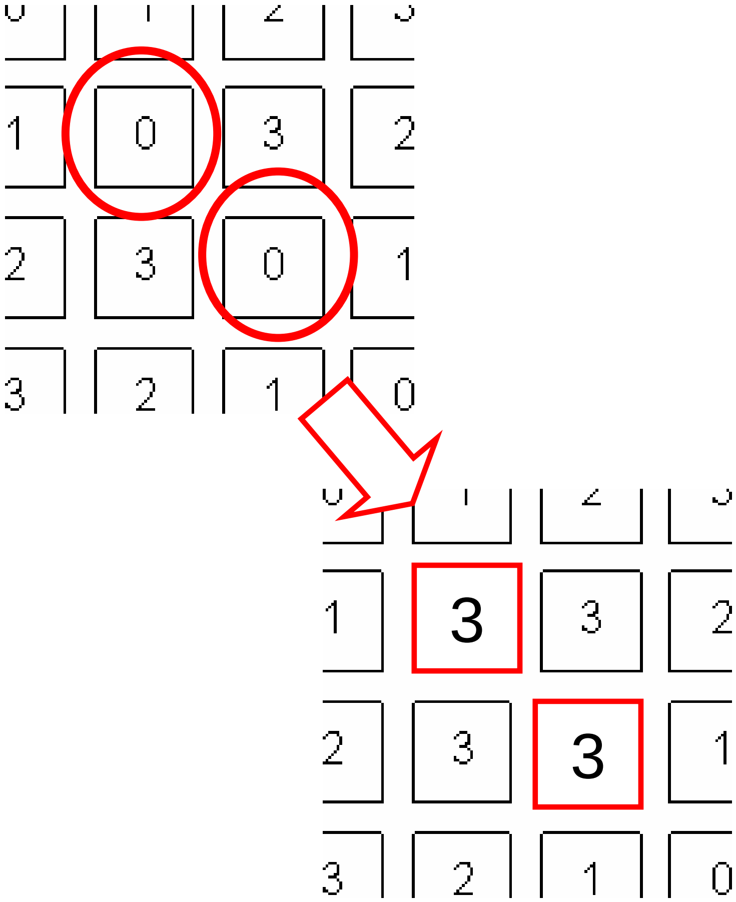
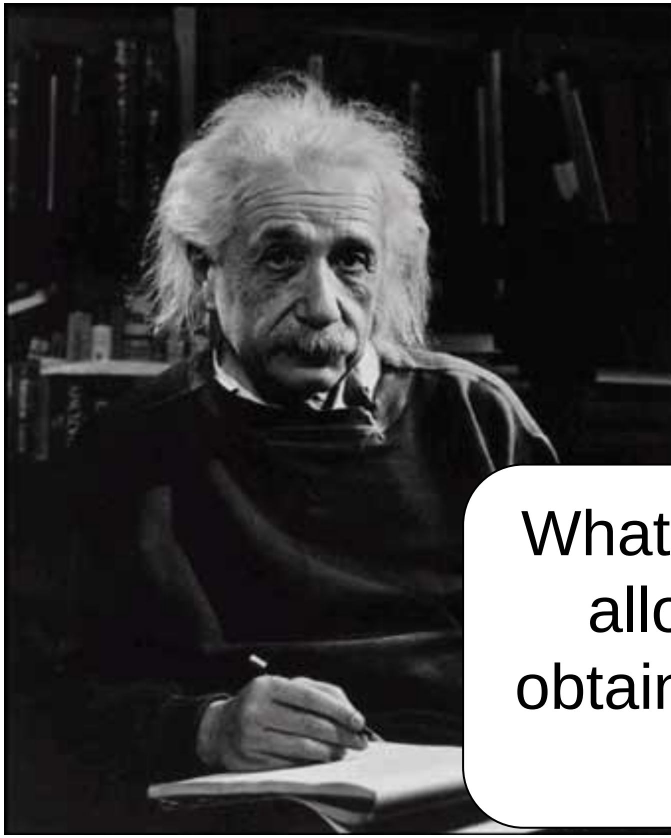


Image Negative



What I see

What operation T allows me to obtain this result?

$g=T(f)$

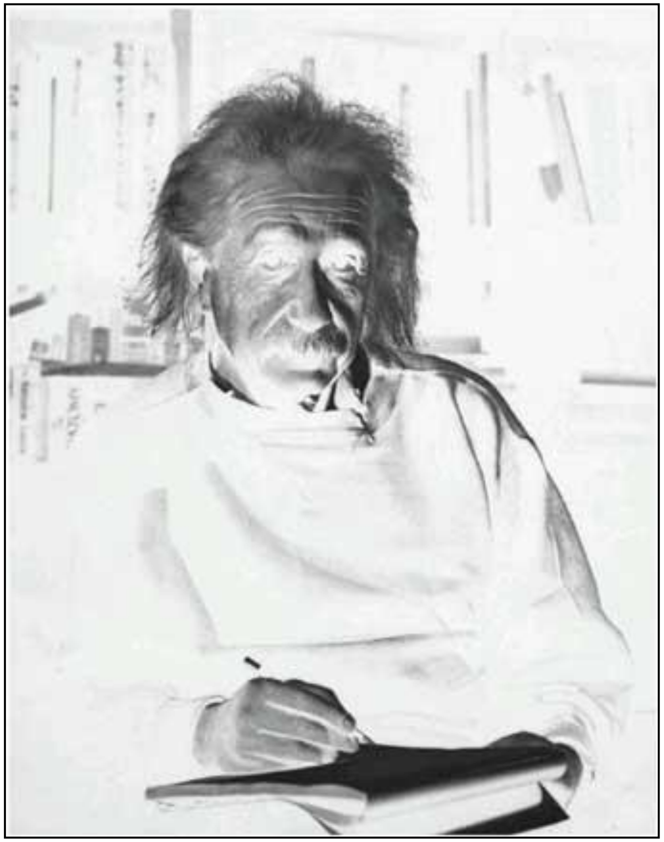
What I <u>want</u> to see

Image Negative

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

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

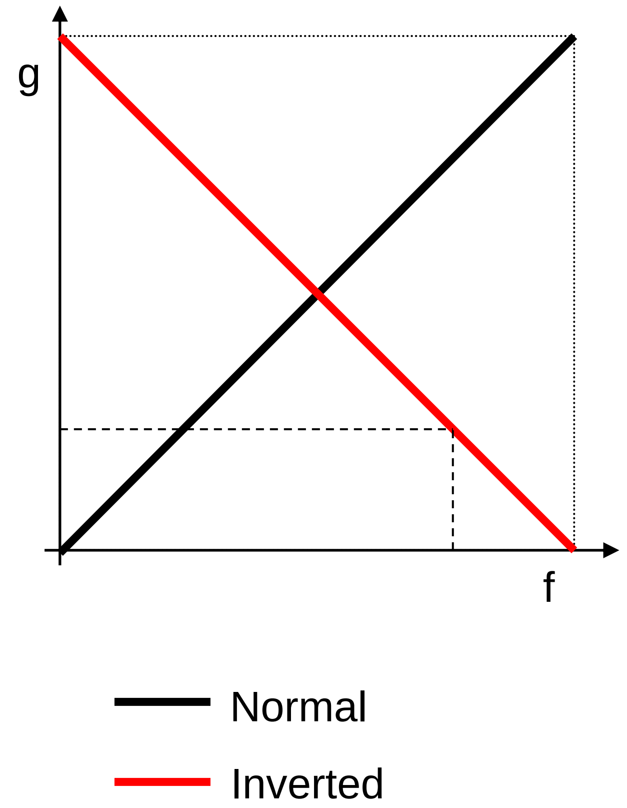
$$g(x,y) = 255 - f(x,y)$$



What I 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



Example – Contrast Stretching

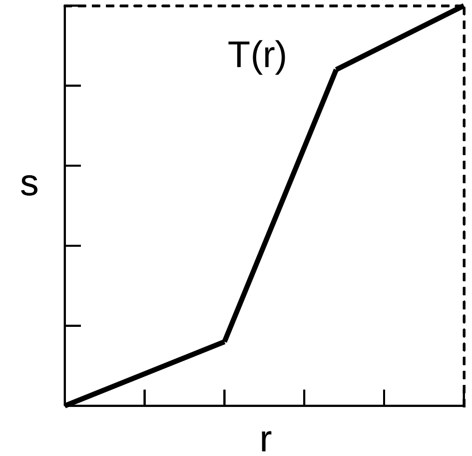
Example – Contrast Stretching

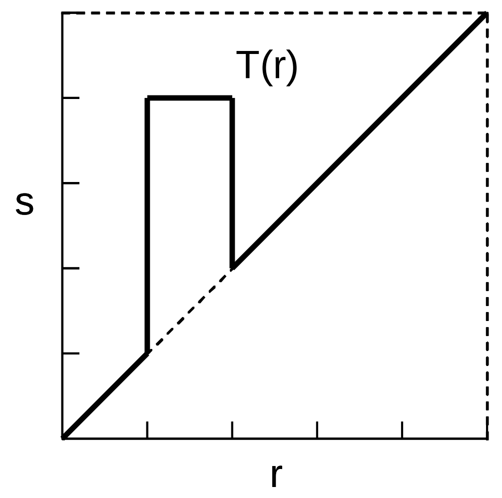
Example – Hist. Equalization

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

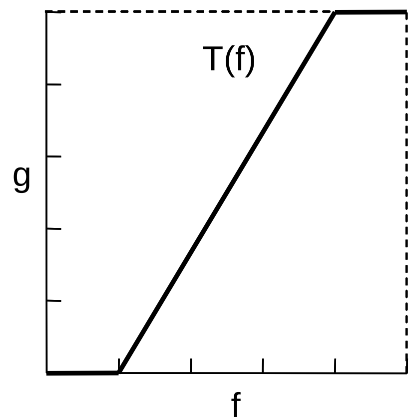




Contrast Stretching

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

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

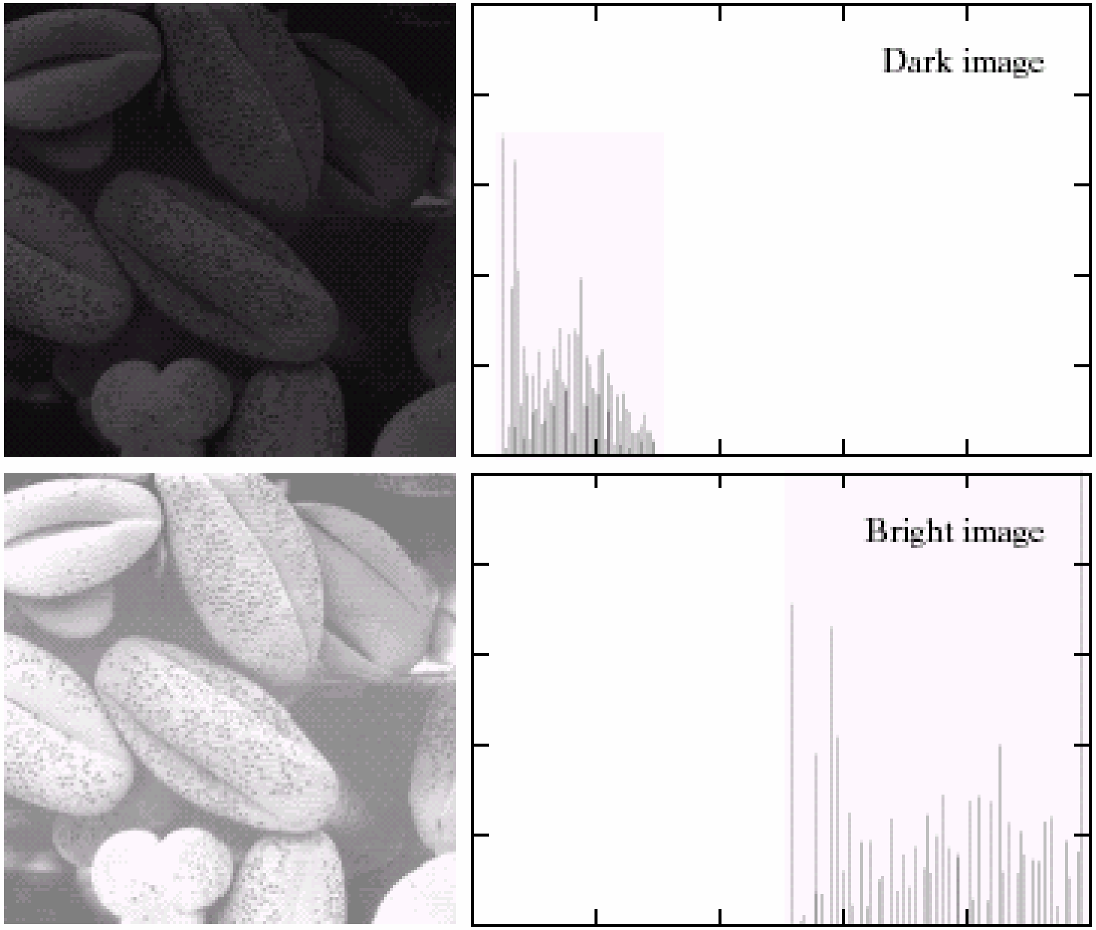


Histogram Processing

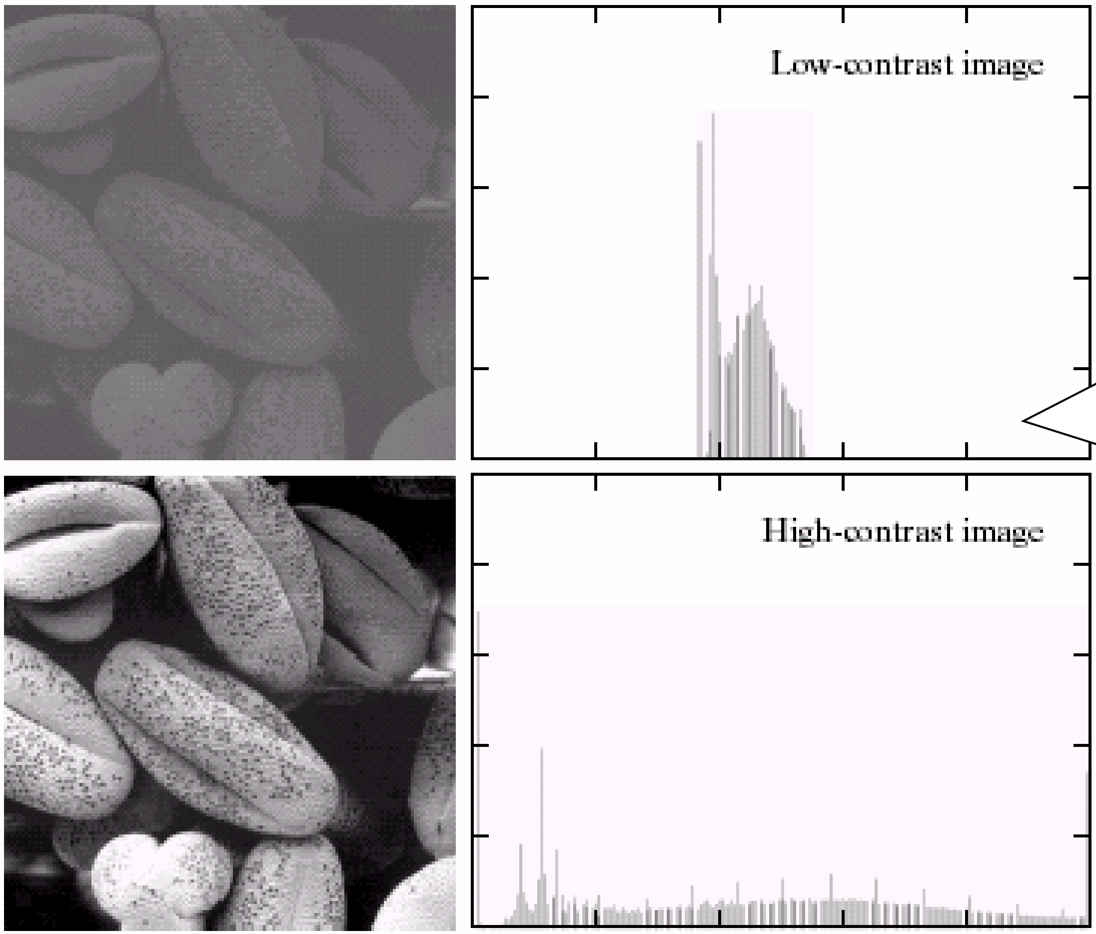
- Histograms give us an idea of how we are using our dynamic range

Types of Image Histograms

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



Types of Image Histograms

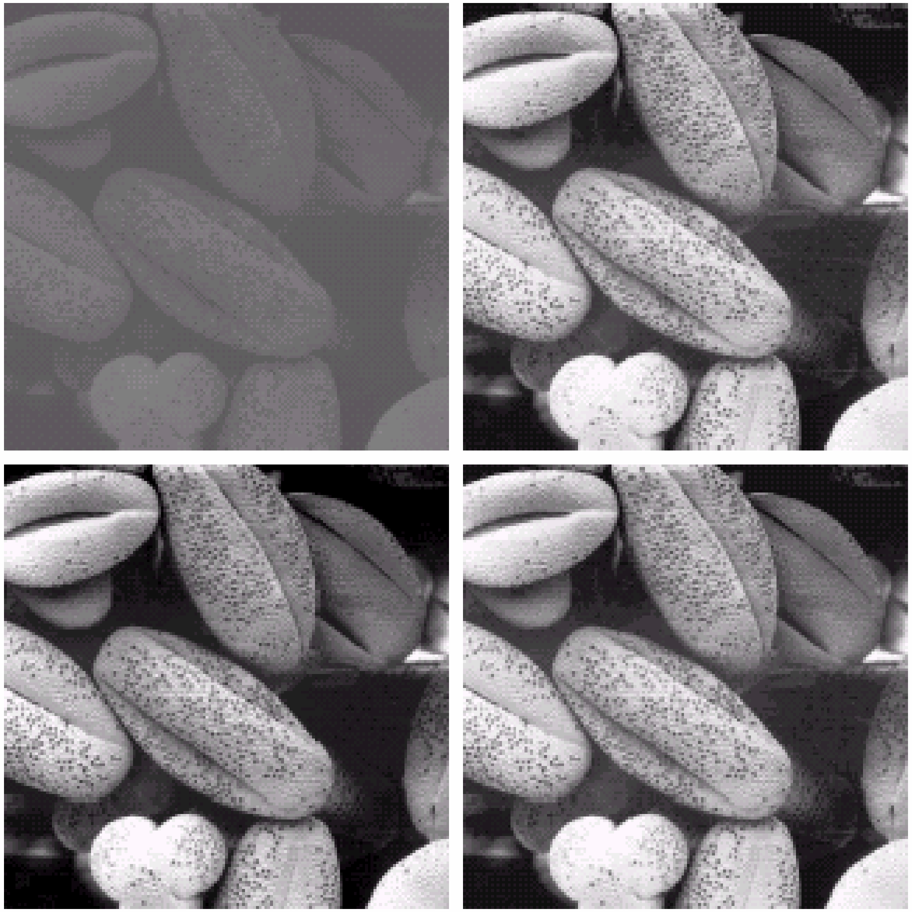


I can manipulate this using single Pixel operations!

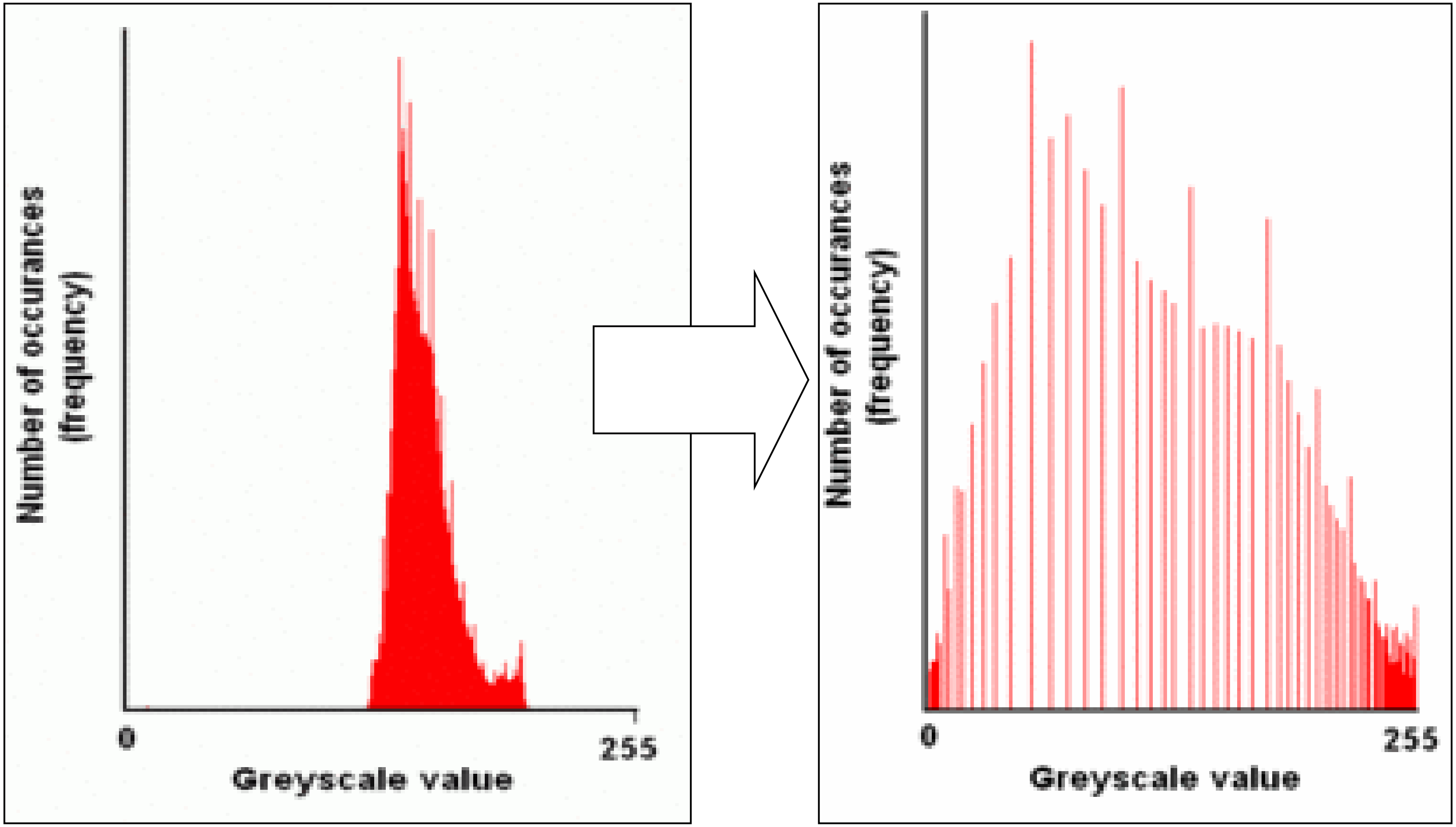
Histogram Equalization

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

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



Histogram Equalization



Sample Question

1. **Digital Image.** Consider an image where the only component of the color present is the *intensity* of each pixel, represented in Figure 1. The image is in digital format, has a 5x5 dimension and an 8-bit quantization.

100	100	100	100	100
150	150	150	150	150
150	150	150	150	150
150	150	200	200	200
200	200	200	200	200

Component I

Figure 1

a) Apply a *contrast stretching operation to* the image represented in Figure 1. Present the calculations performed and the final result in matrix form (2 points).

Sample Question

1. **Digital Image.** Consider a RGB image, where the color components of each pixel are represented in the matrices in Figure 1. The image is in digital format, has a 3x3 resolution and has a 4-bit quantization.

0	0	0
10	10	12
10	10	12

R Component

3	3	3
4	4	4
4	4	4

G Component

6	6	6
10	10	8
10	10	8

B Component

Figure 1

a) Calculate the *intensity* I (HSI color space) of the color of each pixel. Present the calculations made, and the final result in matrix form. (2 points)

b) Apply a *histogram equalization* operation to the B component of the image represented in Figure 1. Present the calculations made and the final result in matrix form. (2 points)

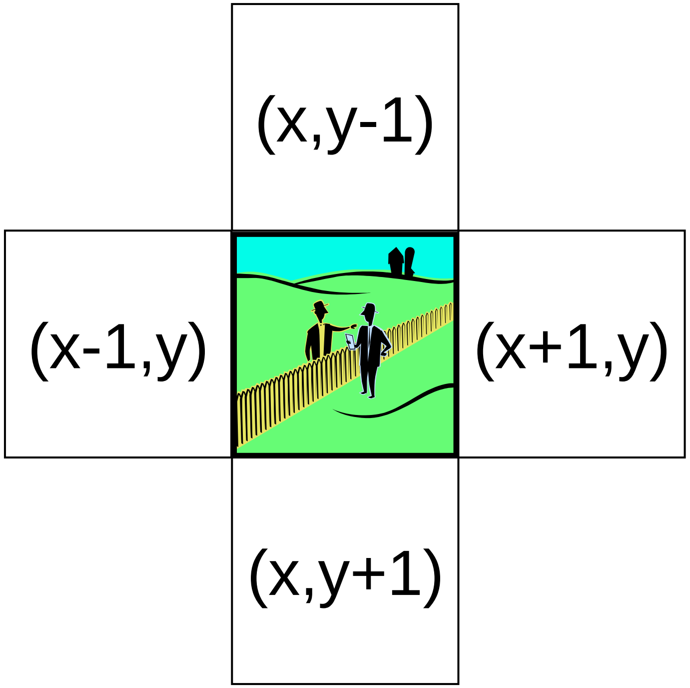
c) What is the usefulness of a *histogram equalization* operation? Compare the characteristics of this algorithm with those of a *contrast stretching* algorithm and explain situations in which it should and should not be applied. (2 points)

Topic: Neighborhoods and Connectivity

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

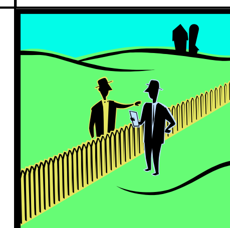
4-Neighbors

- 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?



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?

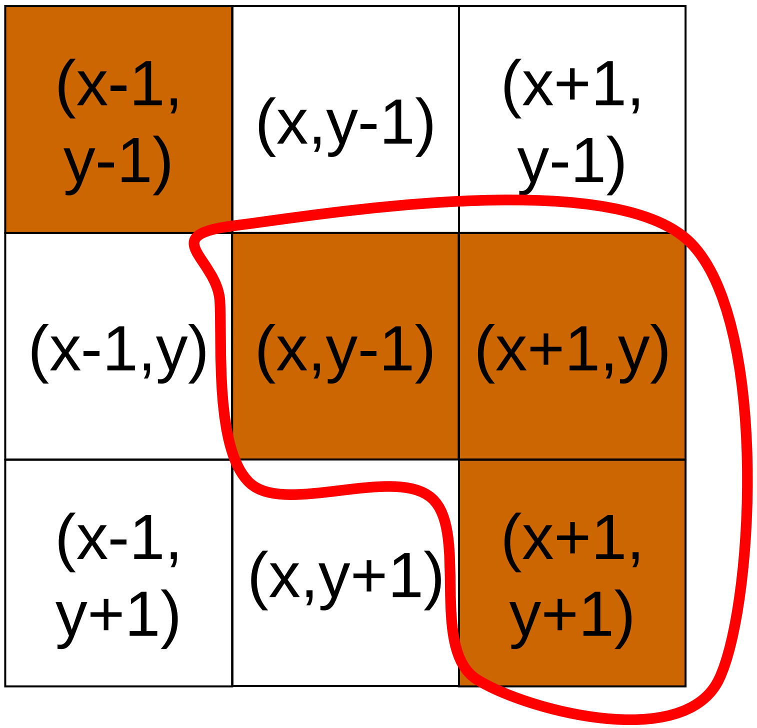
(x-1, y-1)	(x,y-1)	(x+1, y-1)
(x-1,y)		(x+1,y)
(x-1, y+1)	(x,y+1)	(x+1, y+1)

Connectivity

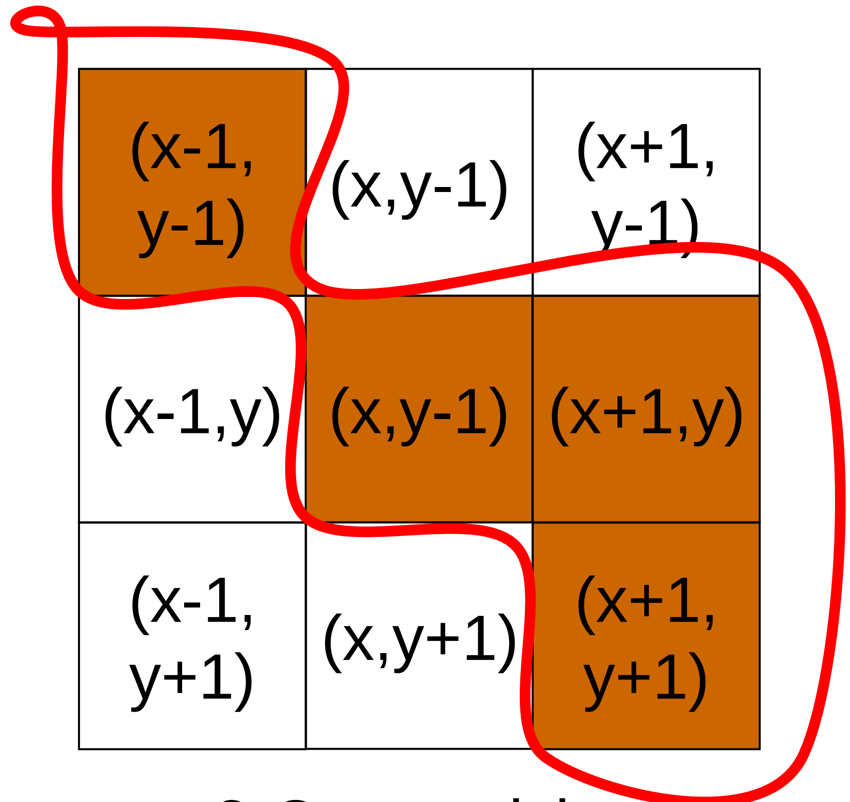
- Two pixels are connected if:
  - They are neighbors (i.e. adjacent in some sense -- e.g. $N_4(p)$, $N_8(p)$, …)
  - Their gray levels satisfy a specified criterion of similarity (e.g. equality, …)

(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

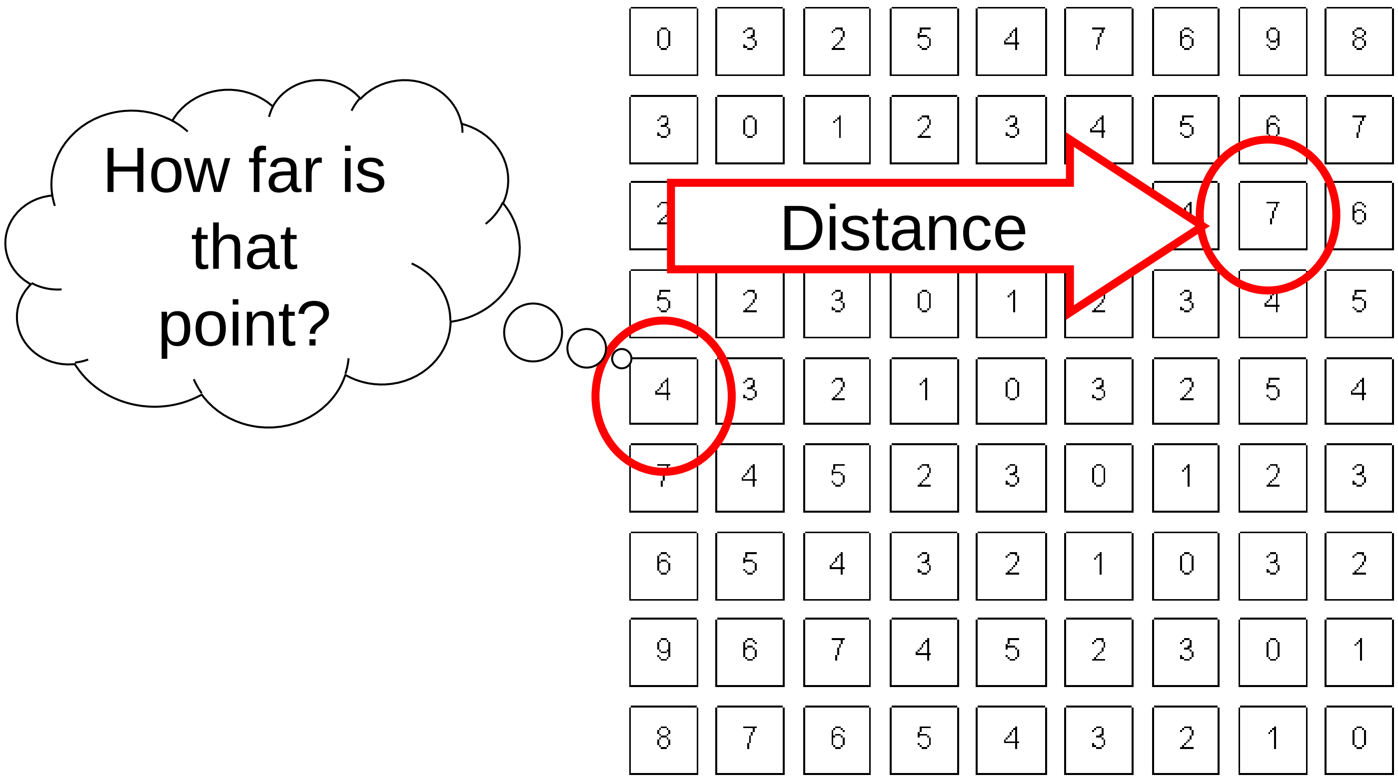


4-Connectivity



8-Connectivity

Distances



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

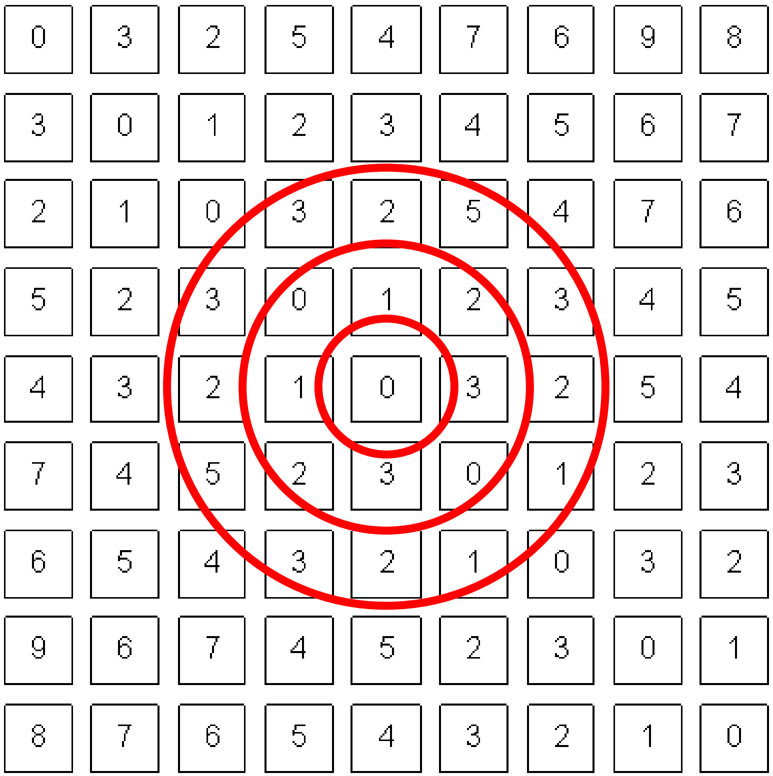
- D_8 distance (chessboard distance):
  - $D_8(p,q) = \max(|x-s|,|y-t|)$
  - Forms a square centered at p
  - e.g. pixels with $D_8 \leq 2$ from p

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
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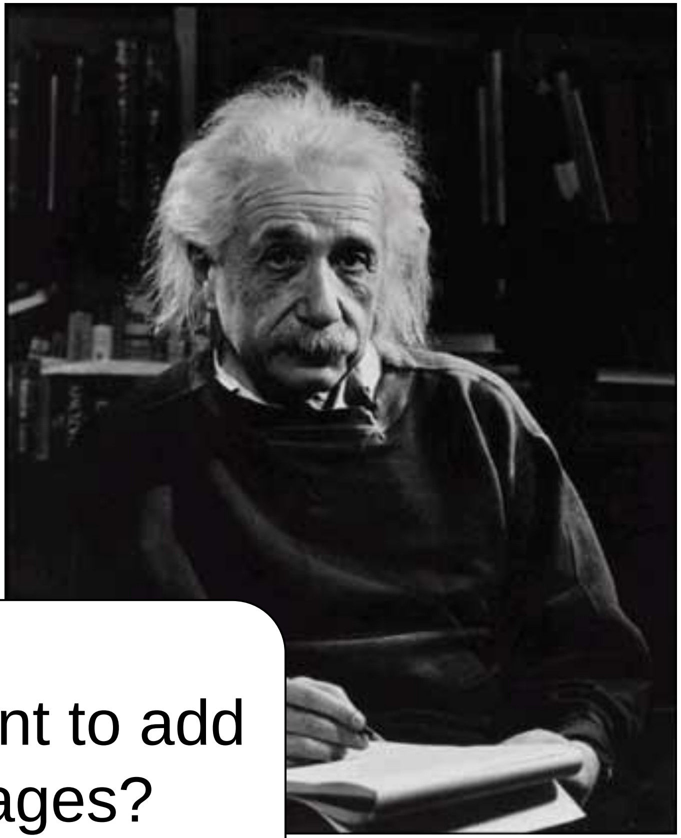
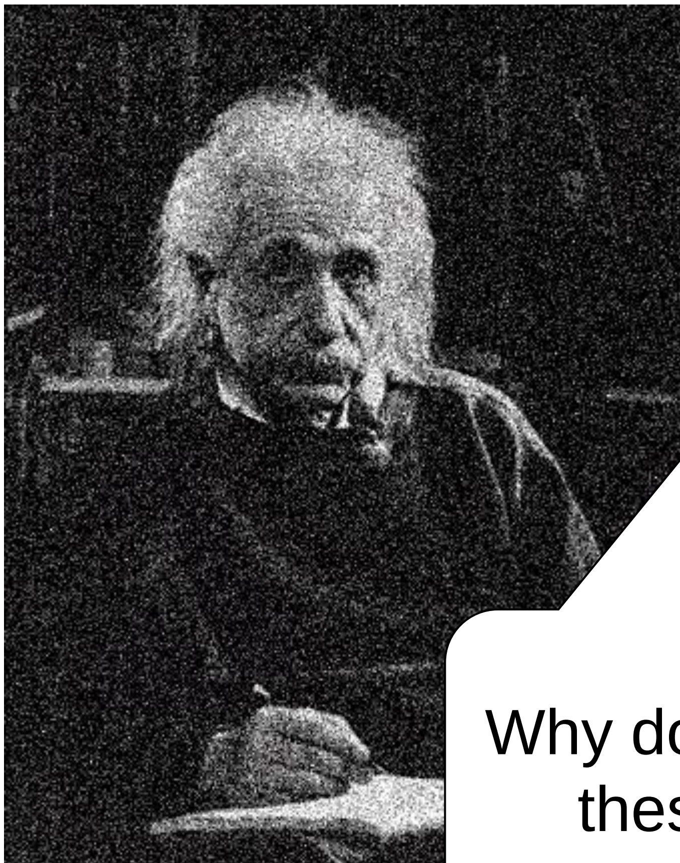
- Example: Background Subtraction

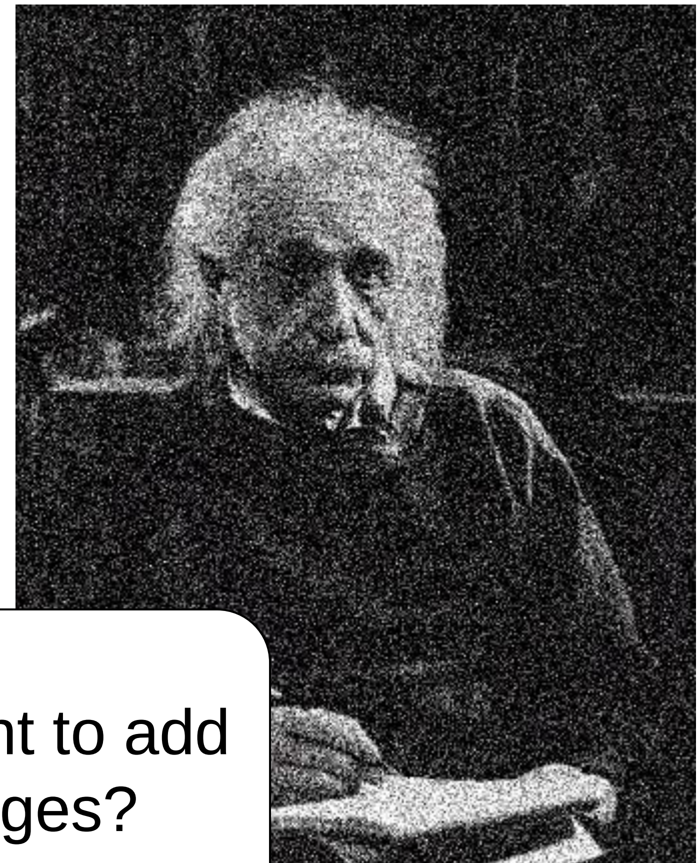
Arithmetic operations between images



Why do I want to add these images?

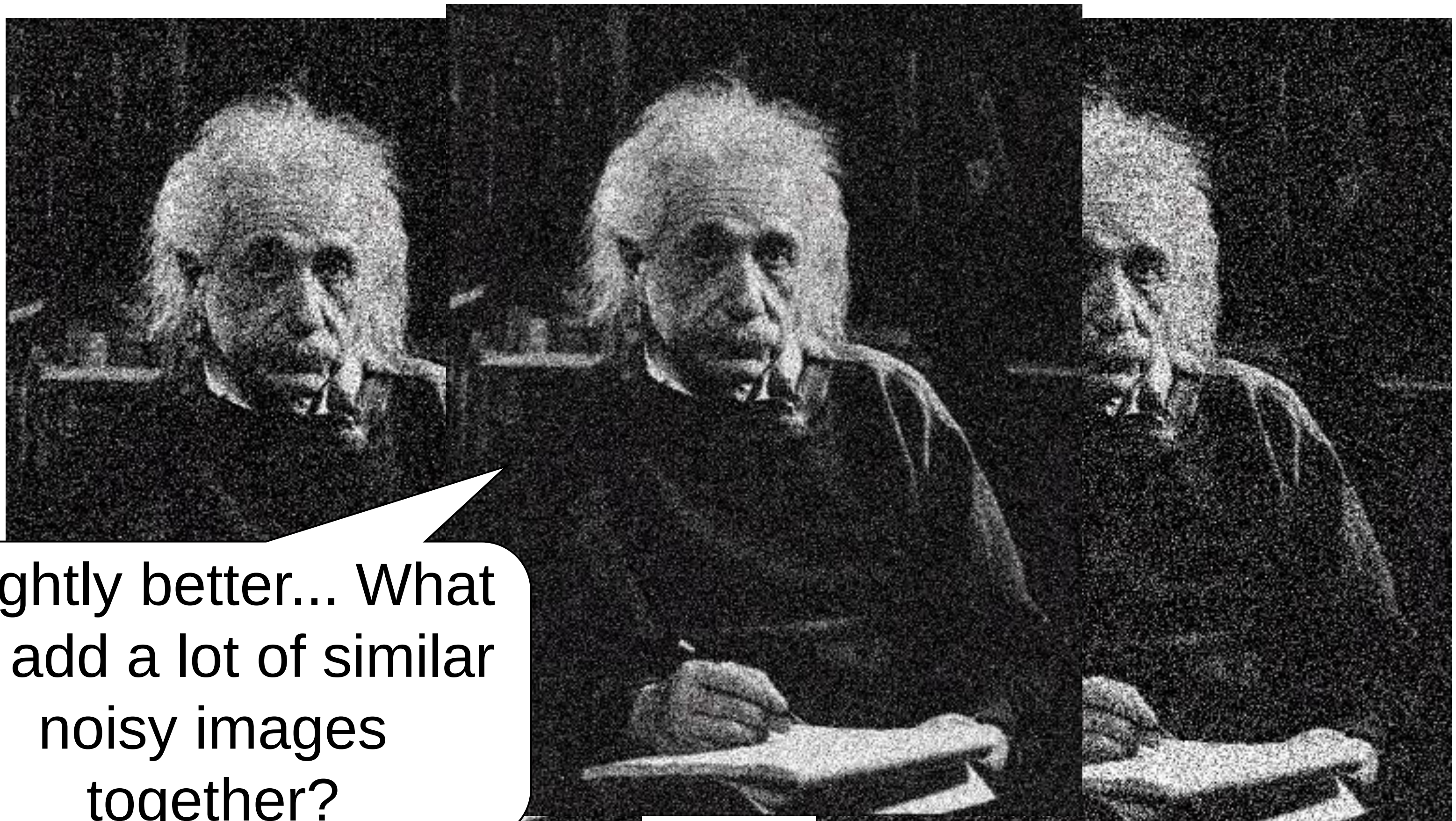
Arithmetic operations between images





Why do I want to add these images?

Arithmetic operations between images

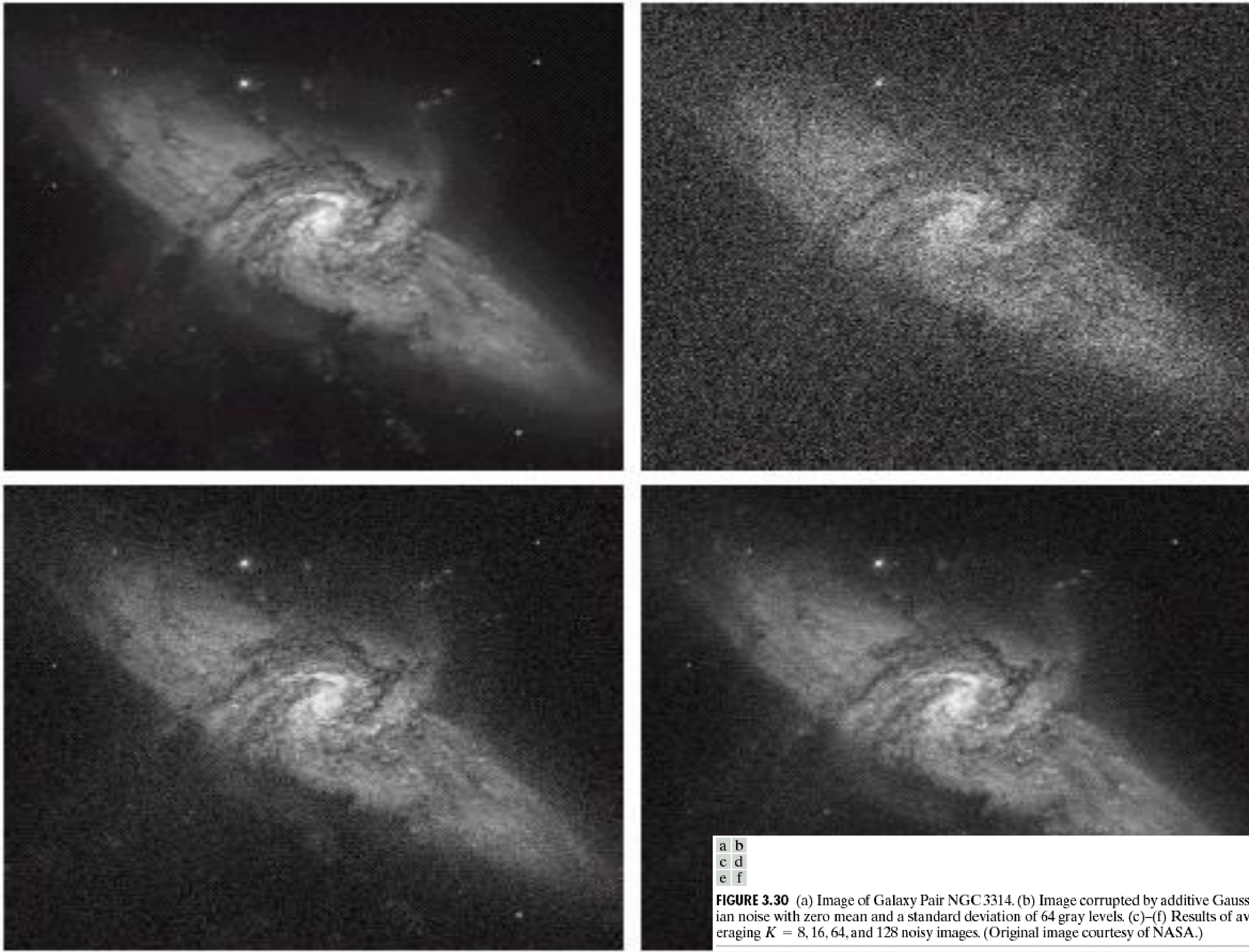


Slightly better... What if I add a lot of similar noisy images together?

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?



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

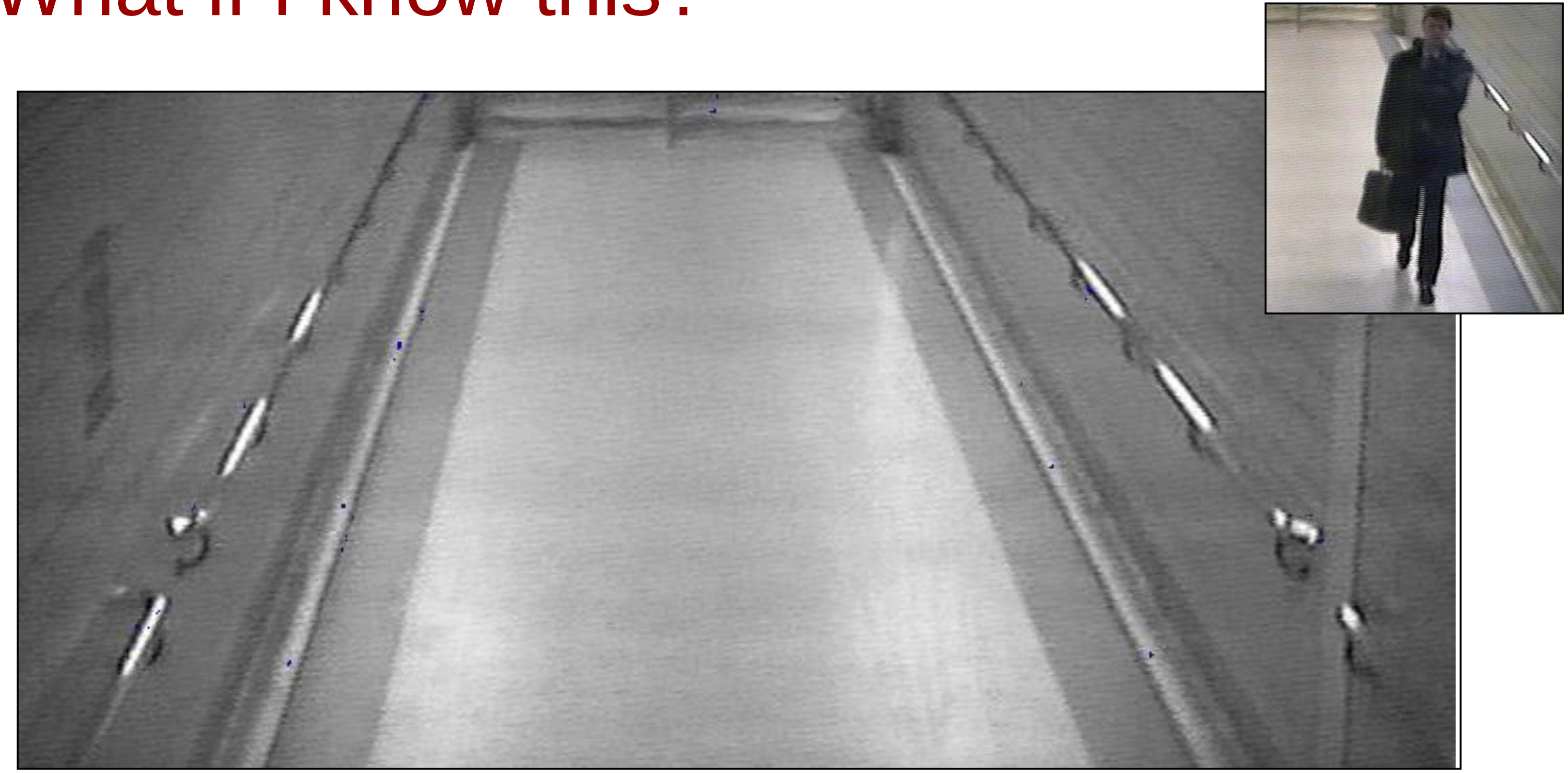
- Remember: We can only see numbers!

Is there a person here? Where?

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
[illegible]	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	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

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

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