VC 11/12 – T5
Single Pixel Manipulation

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos

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U. PORTO FC

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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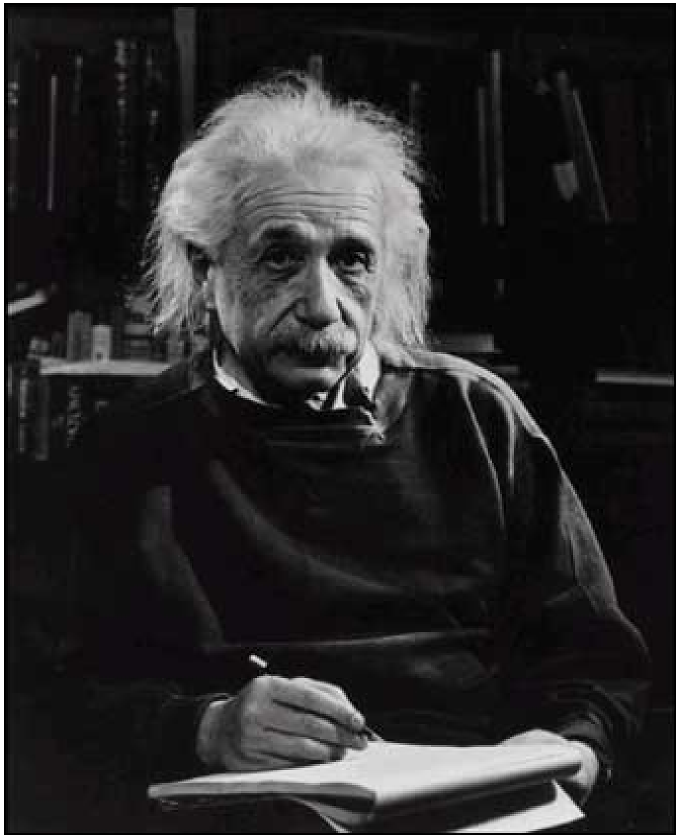
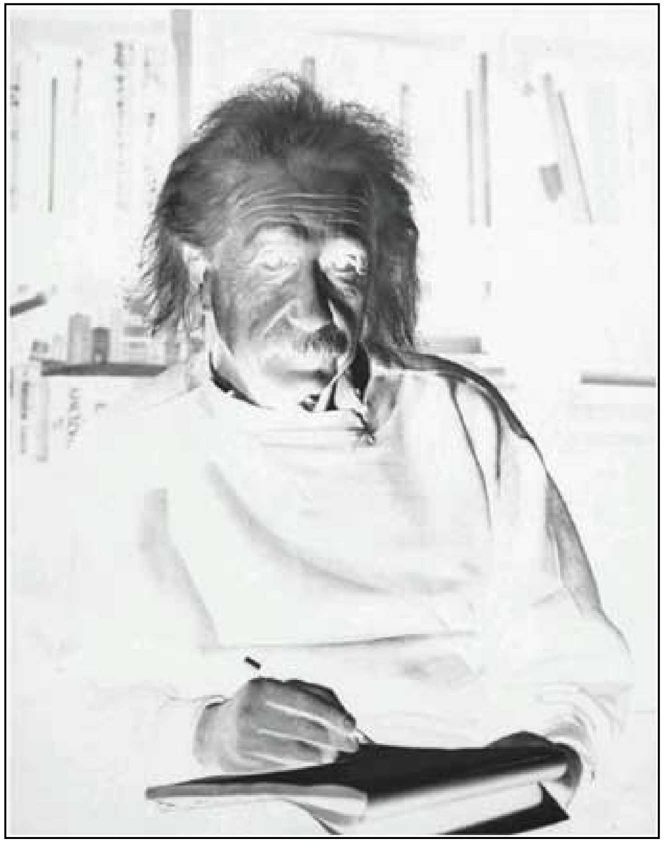
Manipulation

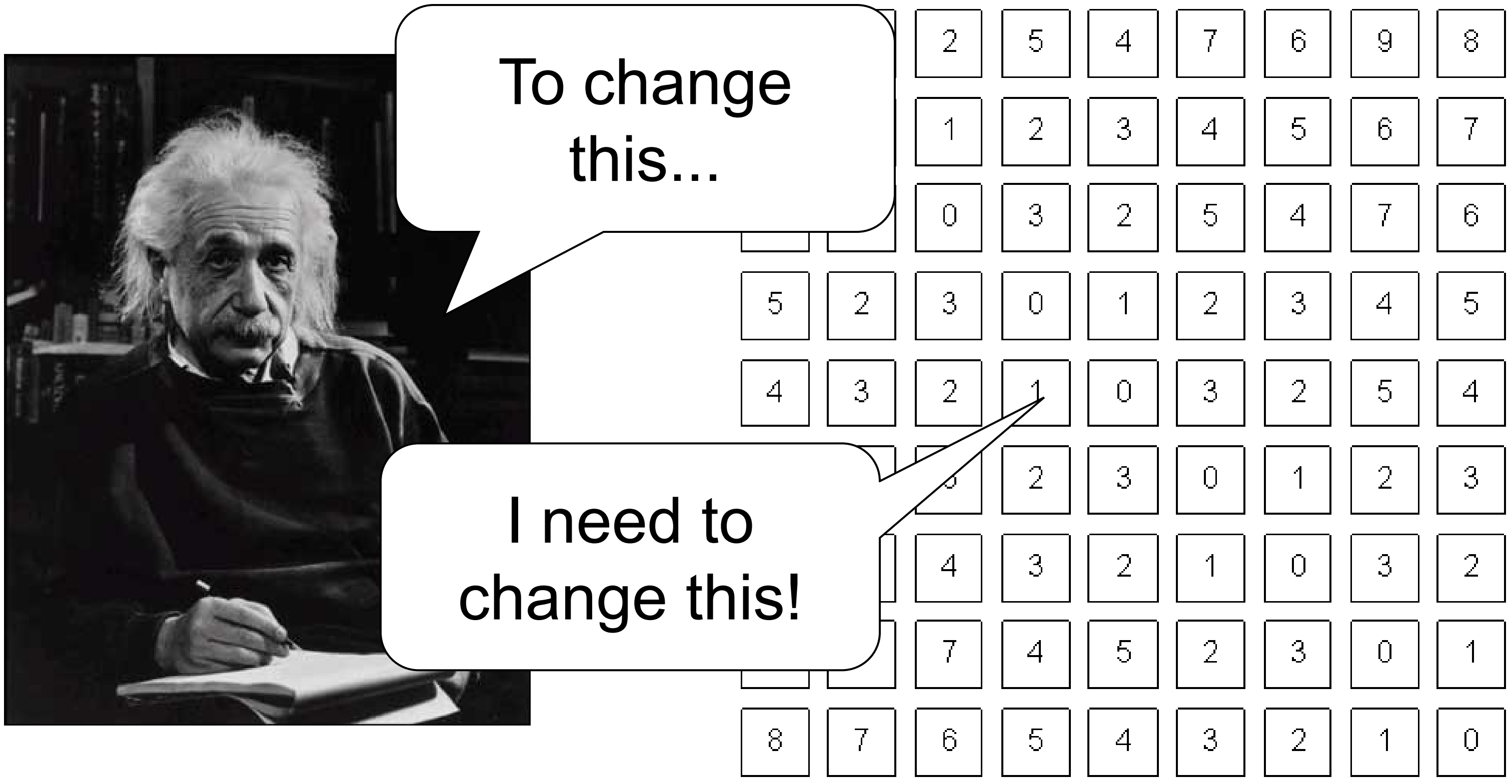


What I see



What I want 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.

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

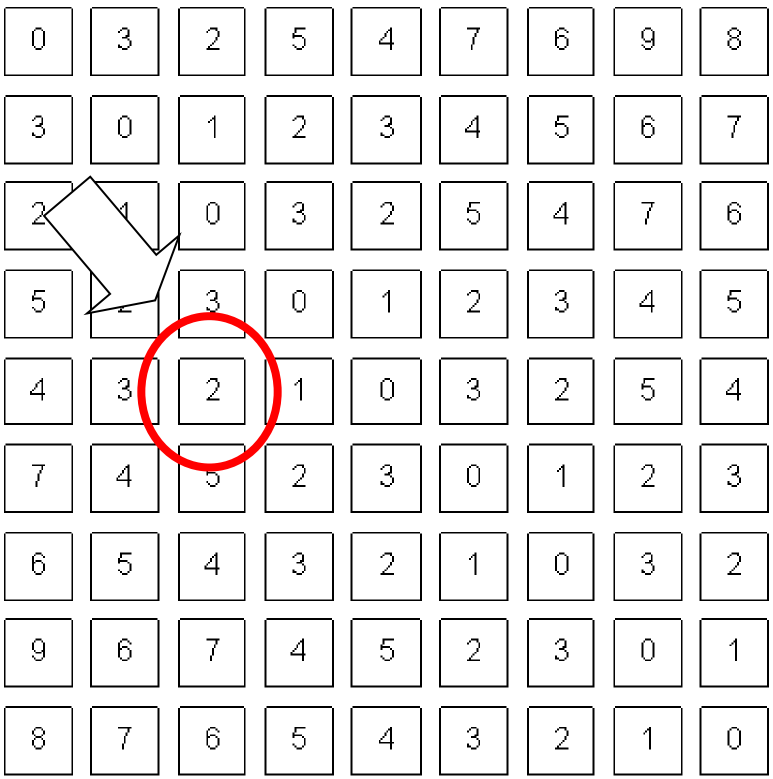


Image Domain

- I am directly changing values of the image matrix.

$$g = T(f)$$

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

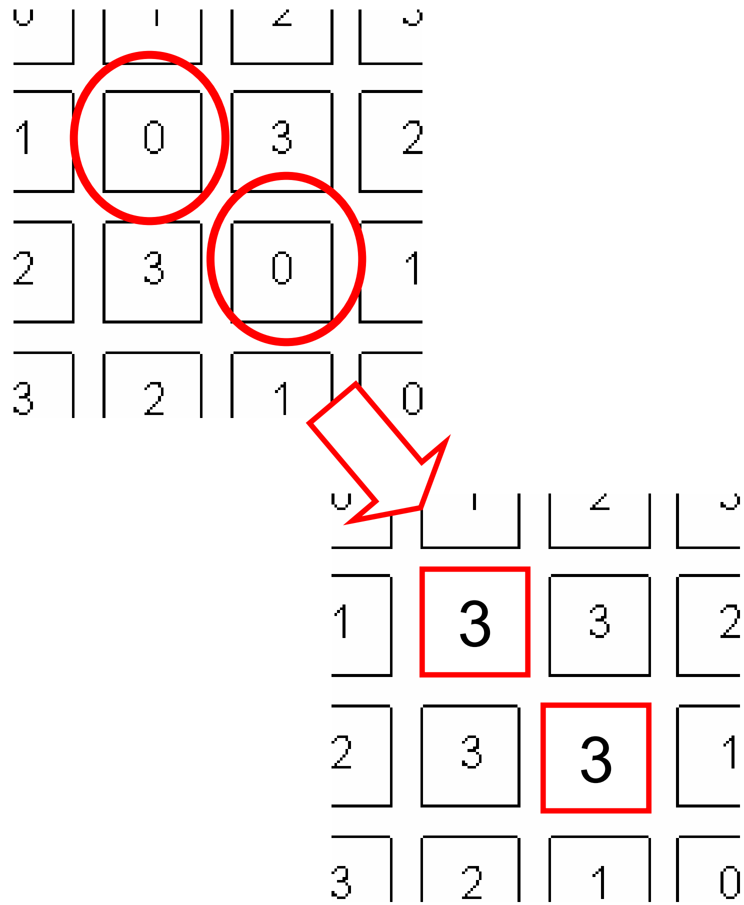
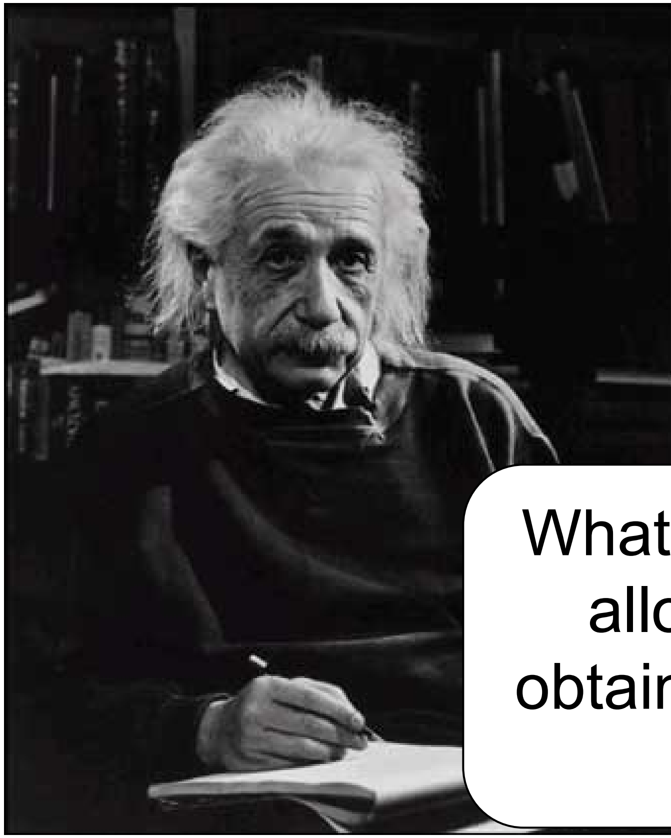


Image Negative



What I see

What operation T allows me to obtain this result?

$g=T(f)$

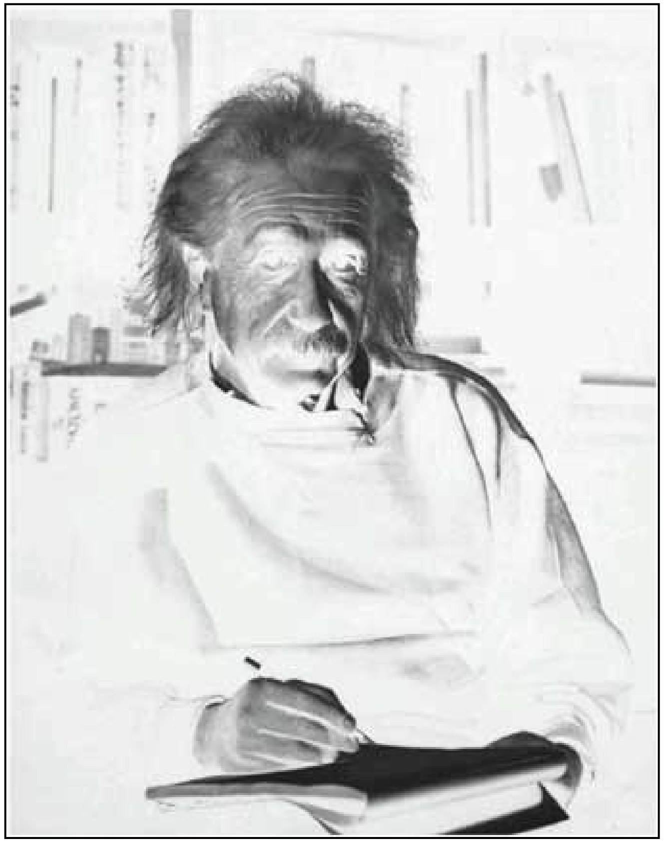
What I want to see

Image Negative

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

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

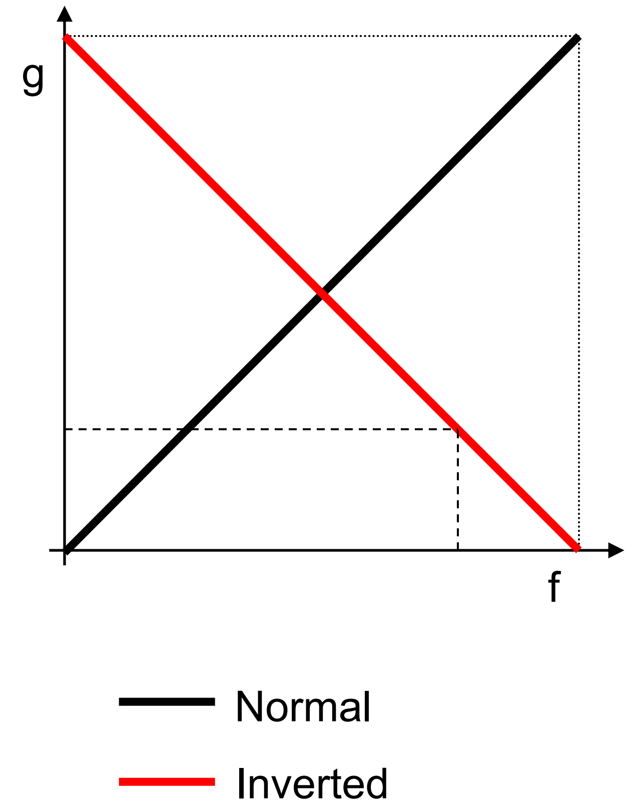
$$g(x,y) = 255 - f(x,y)$$



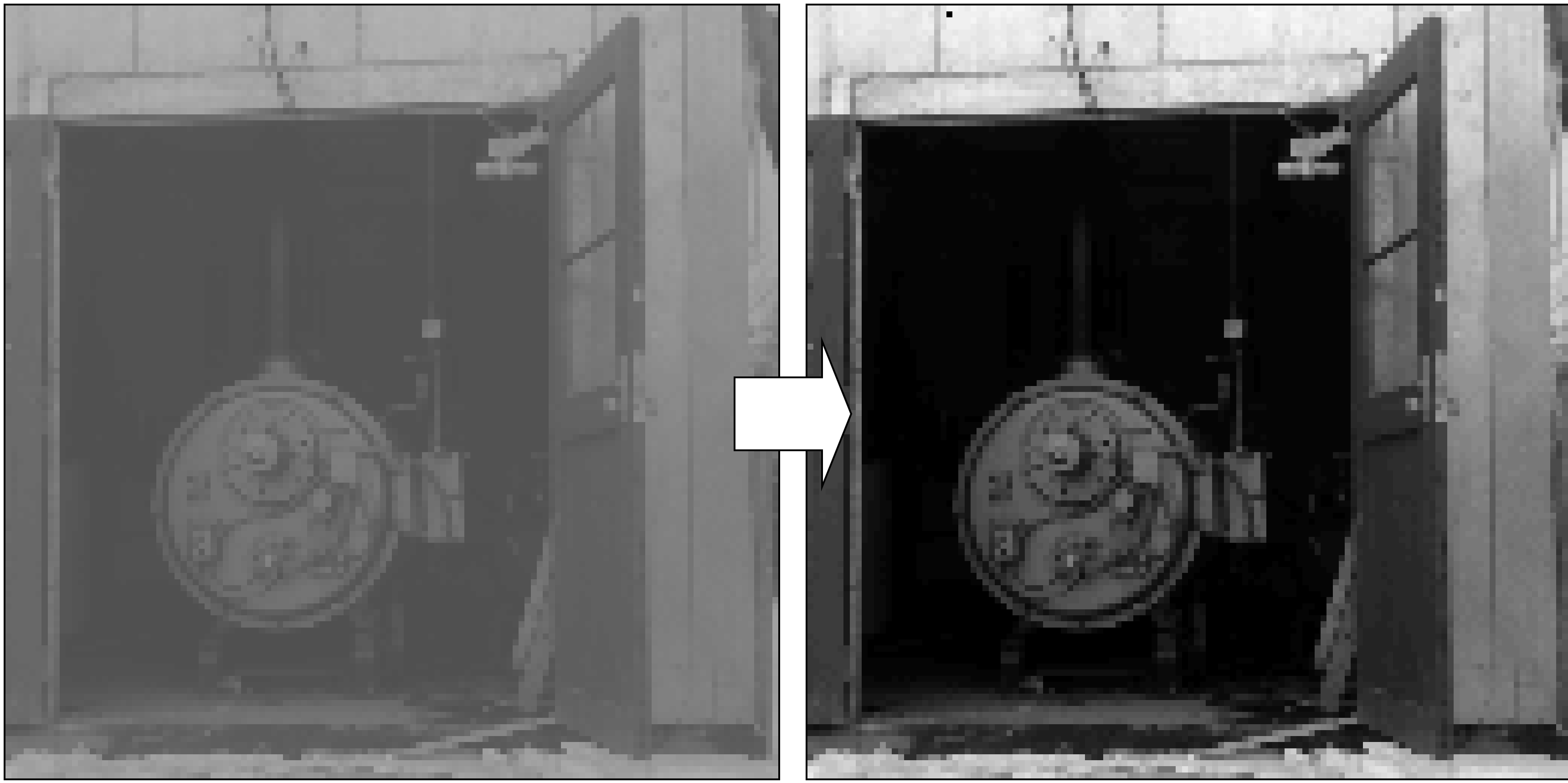
What I <u>want</u> to see

Dynamic Range Manipulation

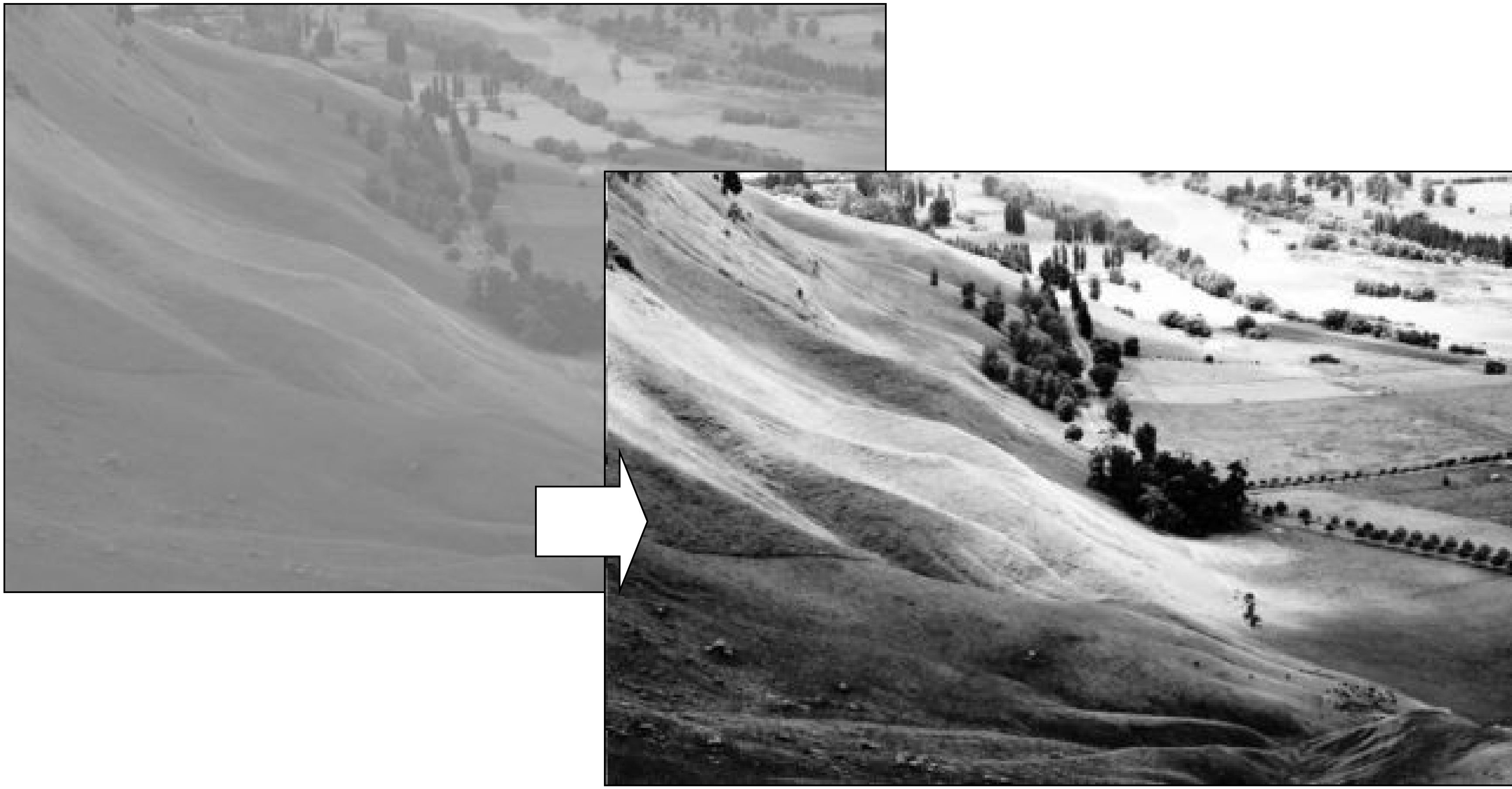
- What am I really doing?
  - Changing the response of my image to the received brightness.
- Dynamic Range Manipulation
  - Represented by a 2D Plot.



Why DRM?

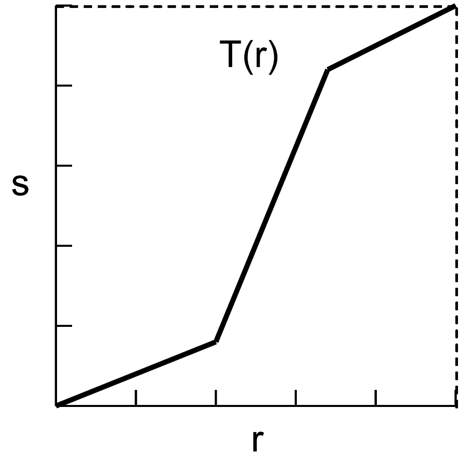


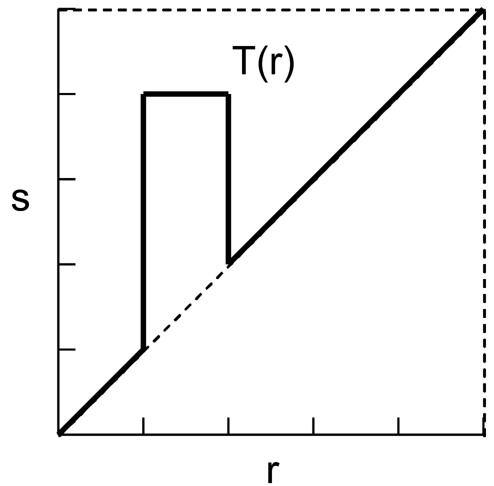
Why DRM?



Other DRM functions

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

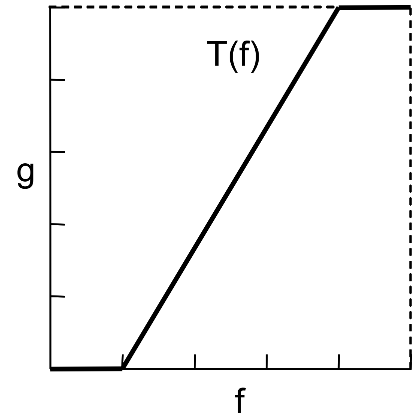




Contrast Stretching

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

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



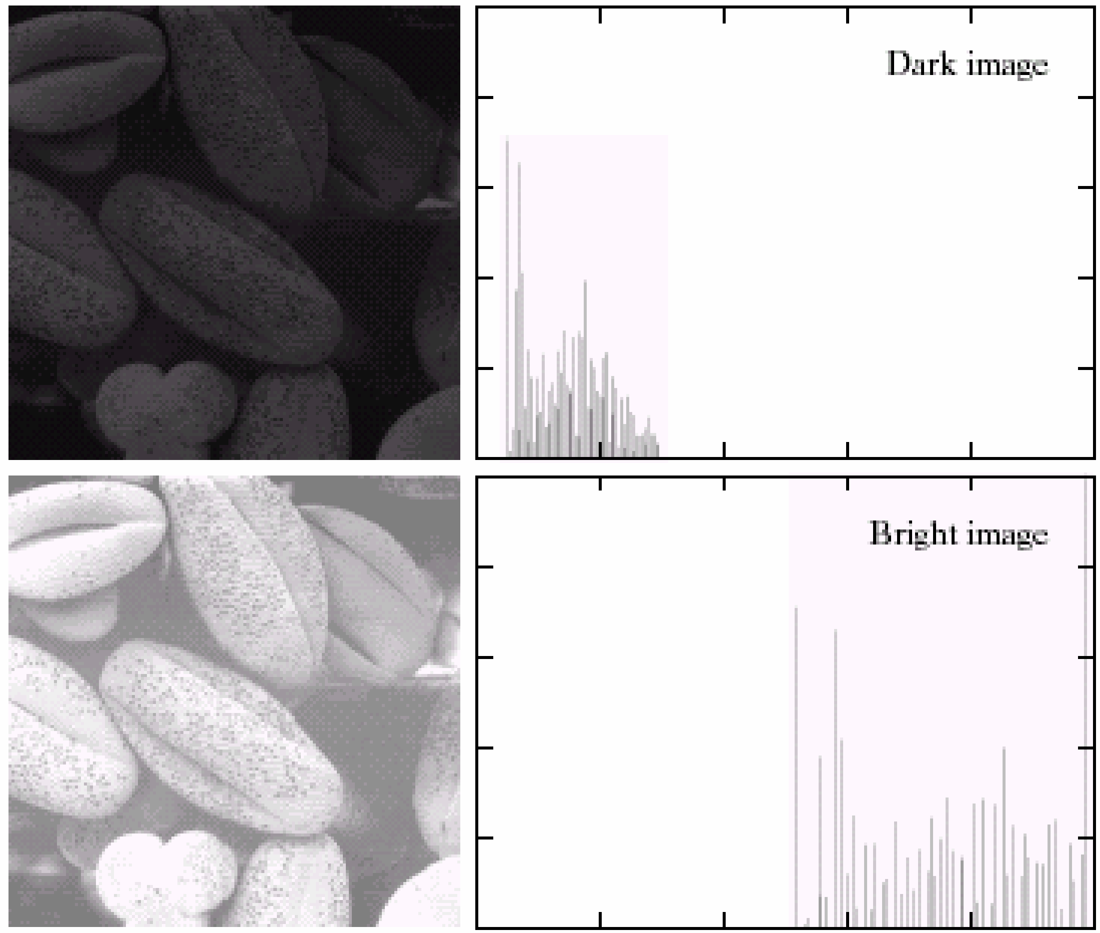
Histogram Processing

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

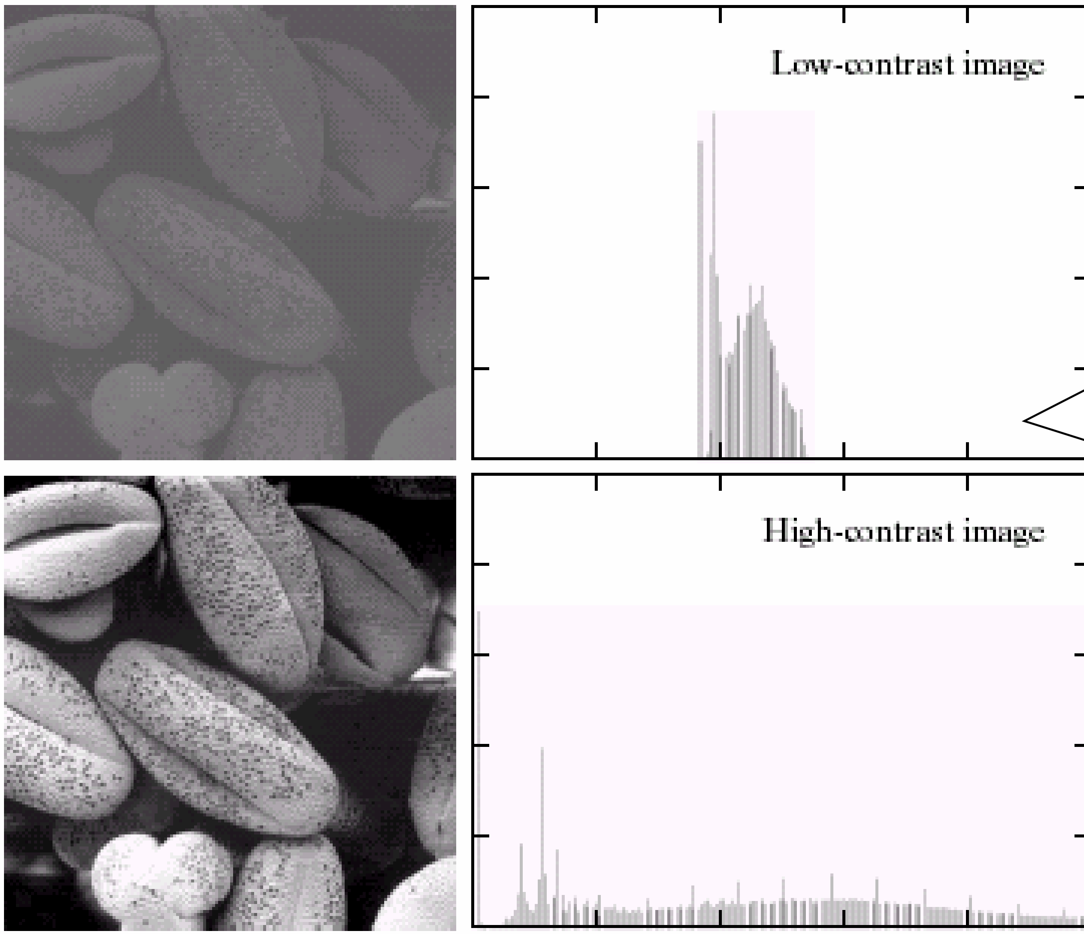
What if I want a different histogram for my image?

Types of Image Histograms

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



Types of Image Histograms

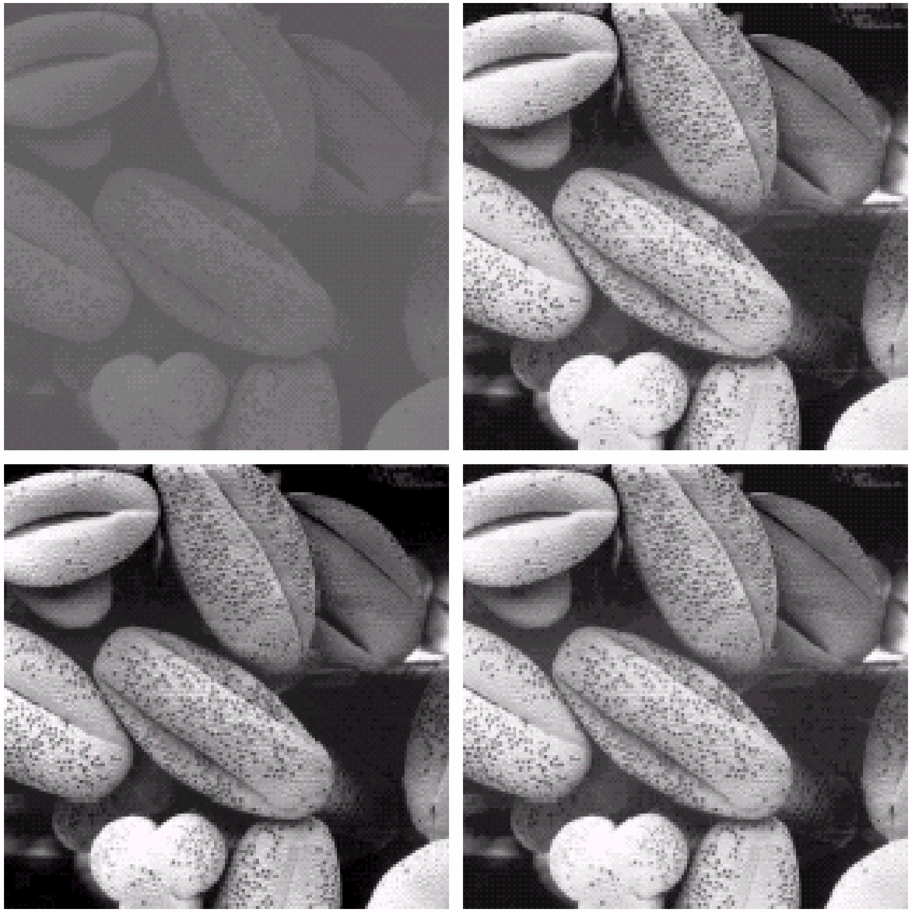


I can manipulate this using single Pixel operations!

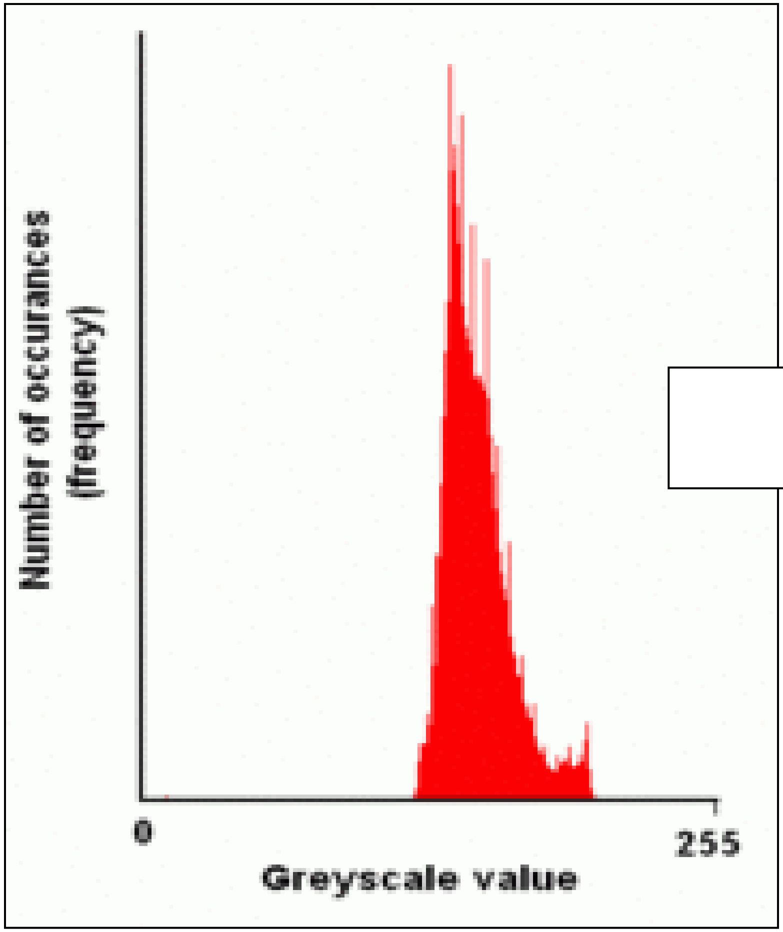
Histogram Equalization

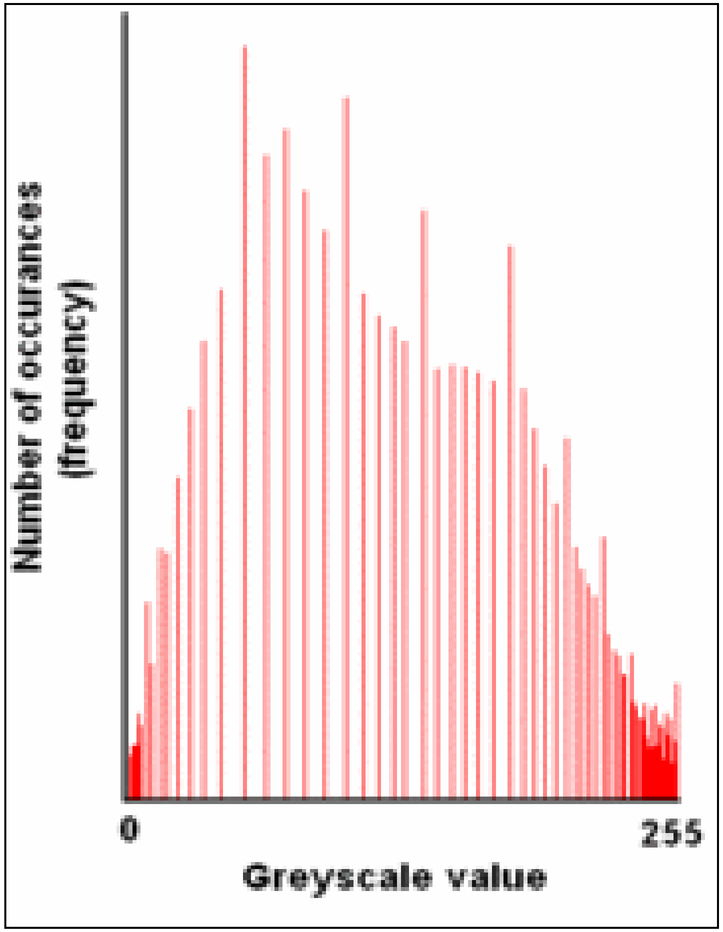
$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j)$$

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



Histogram Equalization



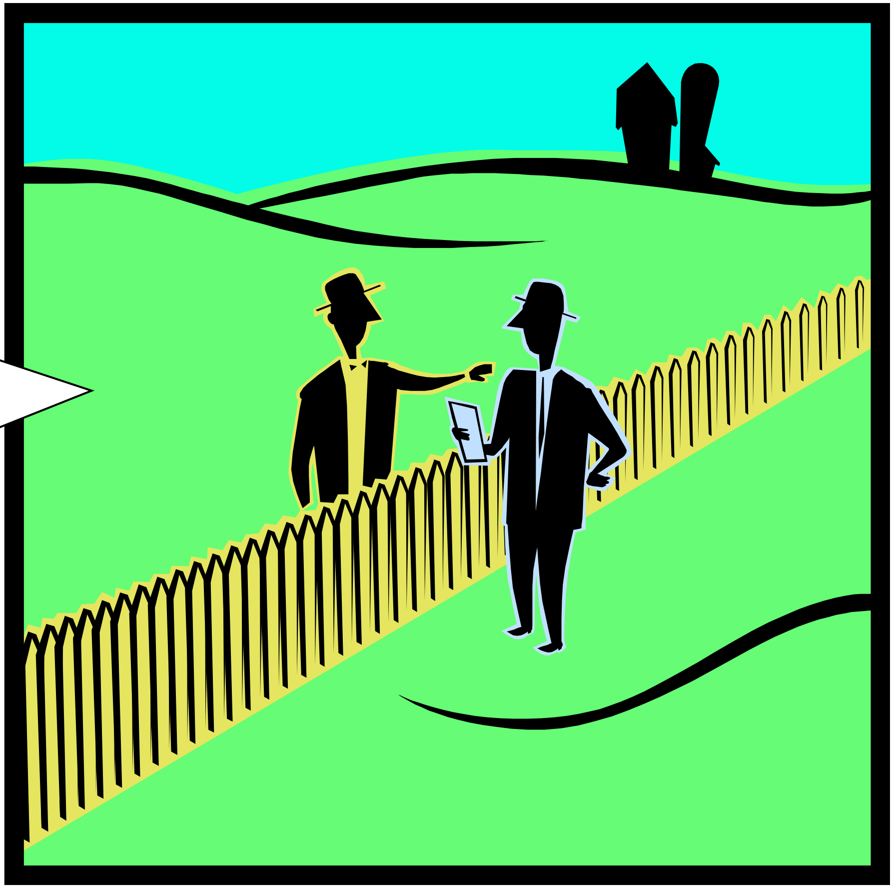


Topic: Neighborhoods and Connectivity

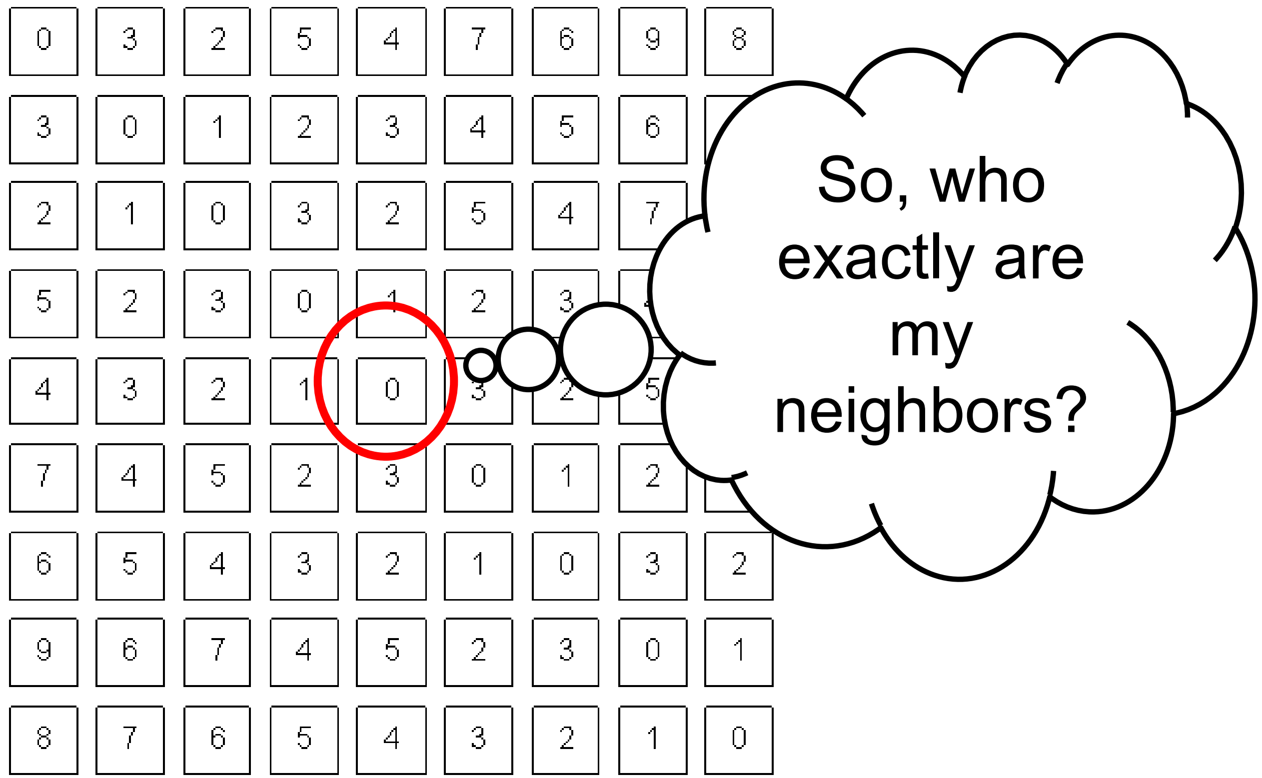
- Dynamic Range Manipulation
- Neighborhoods and Connectivity
- Image Arithmetic
- Example: Background Subtraction

Neighbors

Why do we care at all?



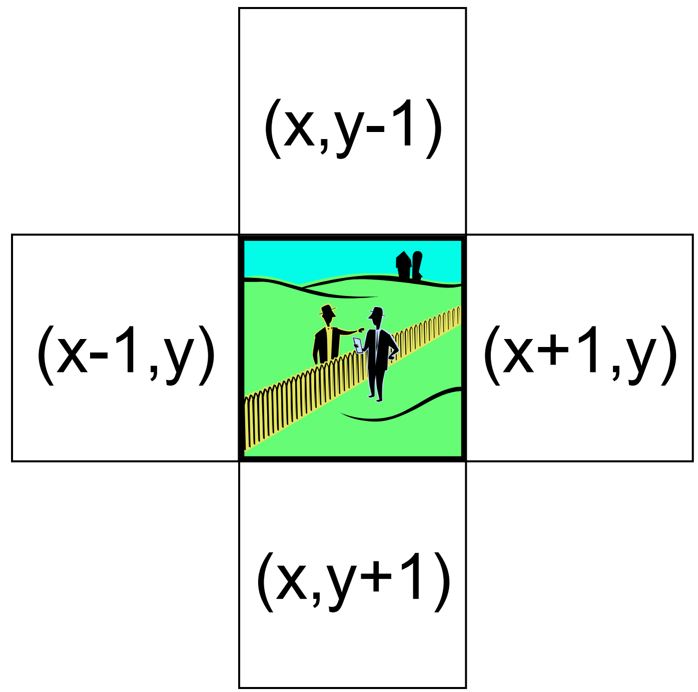
Digital Images



What a computer sees

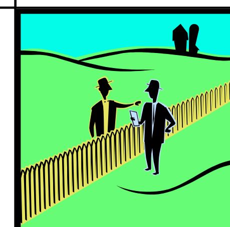
4-Neighbors

- 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?

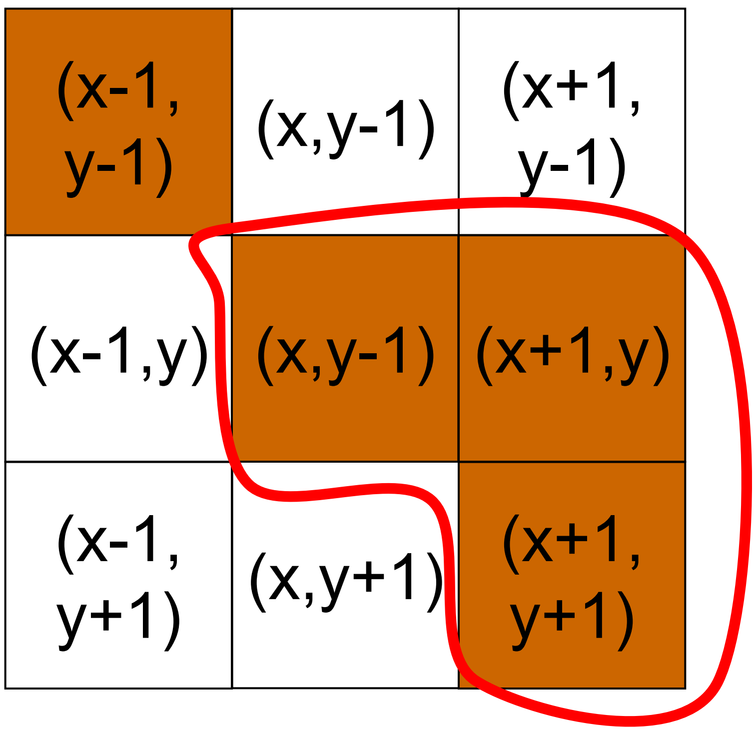
(x-1, y-1)	(x,y-1)	(x+1, y-1)
(x-1,y)		(x+1,y)
(x-1, y+1)	(x,y+1)	(x+1, y+1)

Connectivity

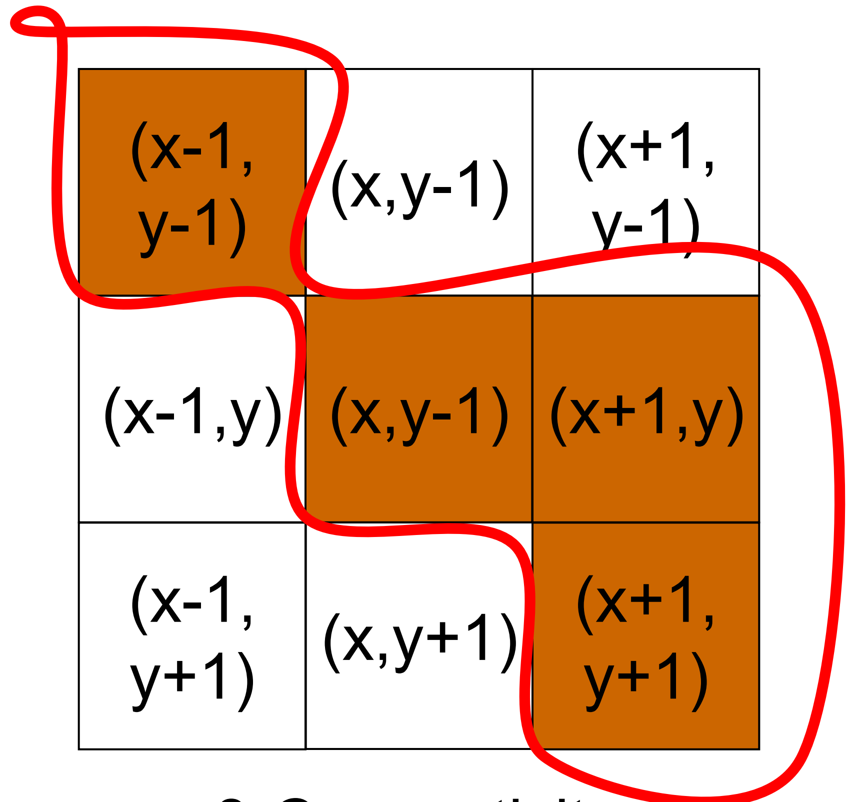
- Two pixels are connected if:
  - They are neighbors (i.e. adjacent in some sense -- e.g. $N_4(p)$, $N_8(p)$, …)
  - Their gray levels satisfy a specified criterion of similarity (e.g. equality, …)

(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

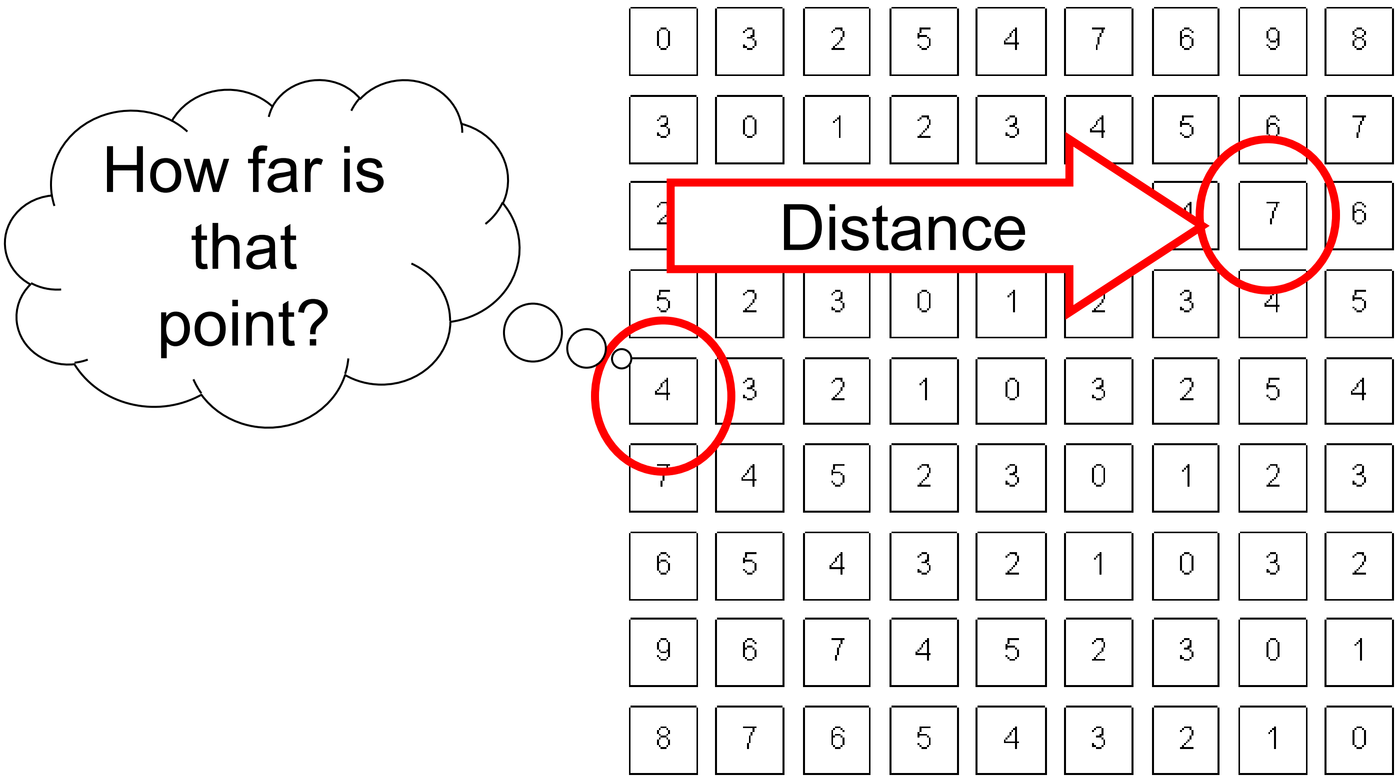


4-Connectivity



8-Connectivity

Distances



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

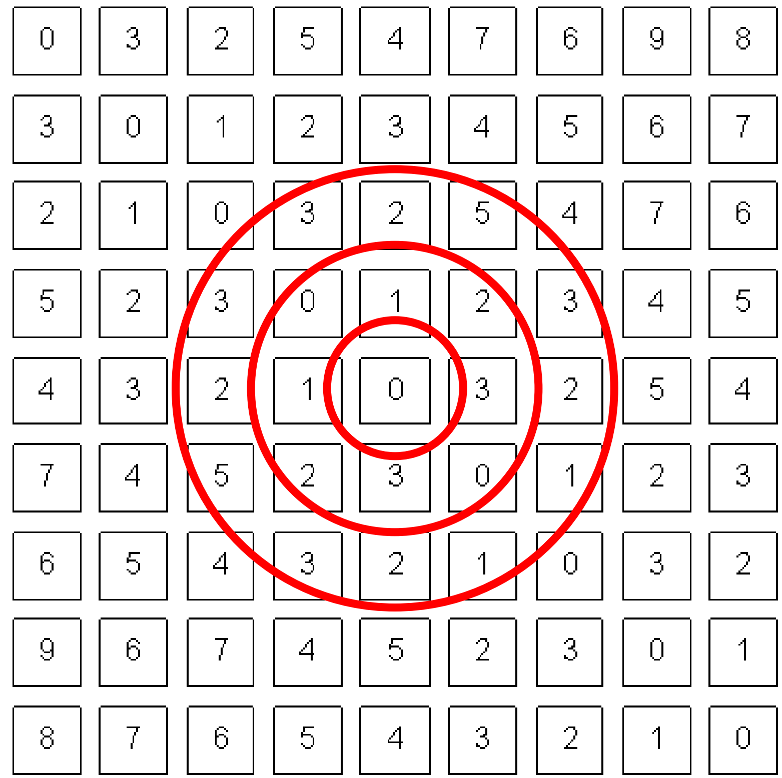
- D_8 distance (chessboard distance):
  - $D_8(p,q) = \max(|x-s|,|y-t|)$
  - Forms a square centered at p
  - e.g. pixels with $D_8 \leq 2$ from p

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

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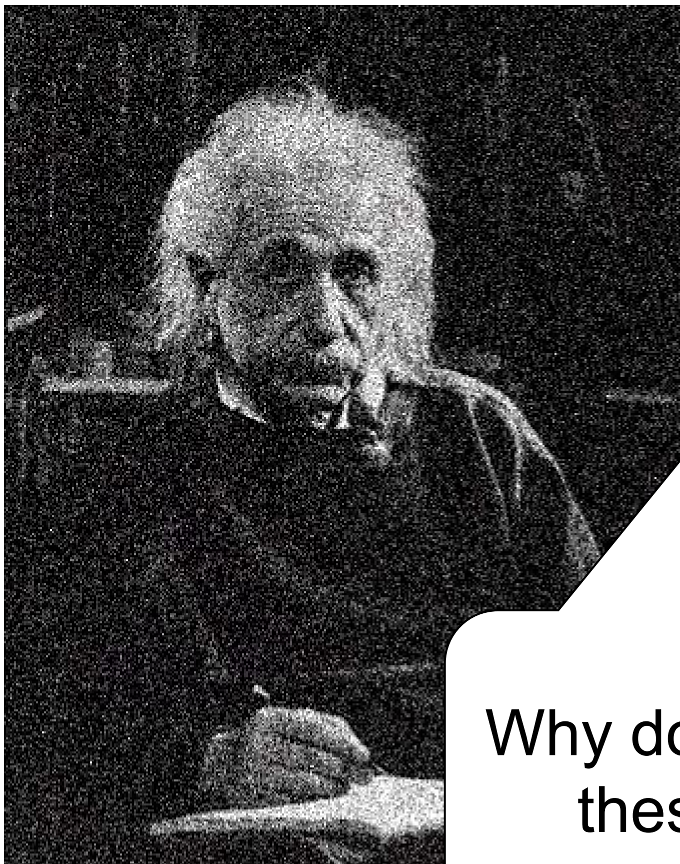
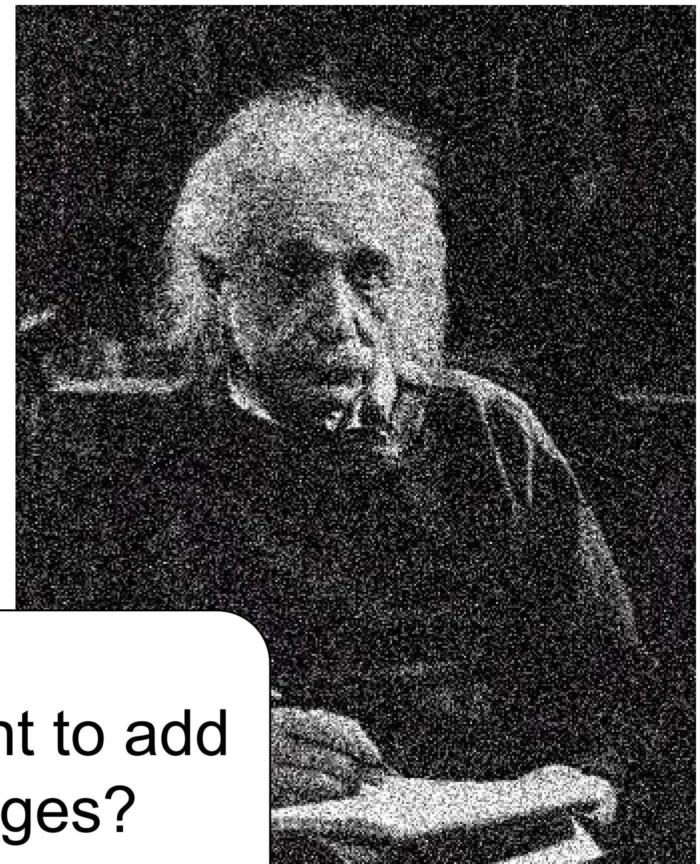
Arithmetic operations between images

Why do I want to add these images?

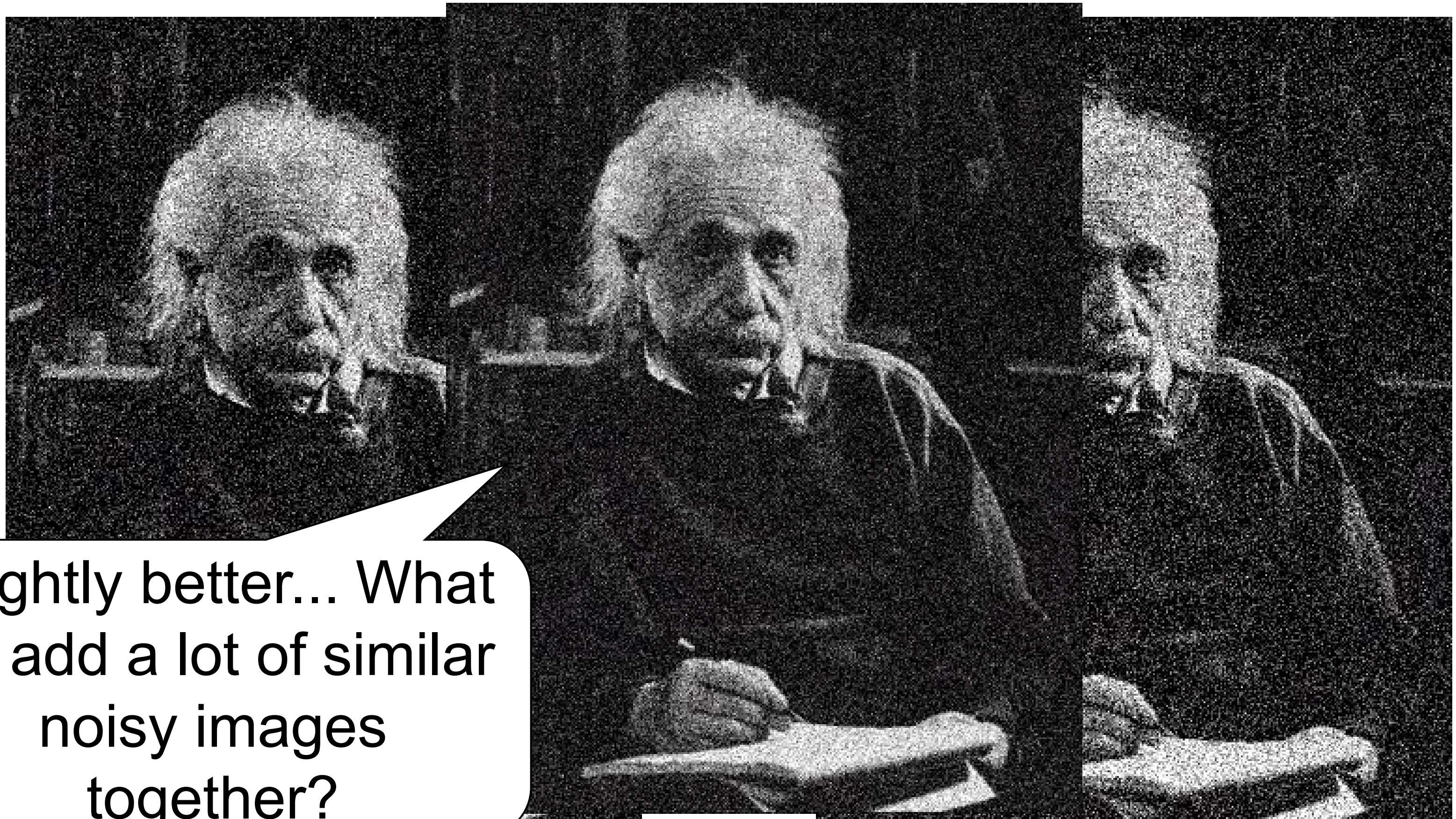
Arithmetic operations between images





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?

Example

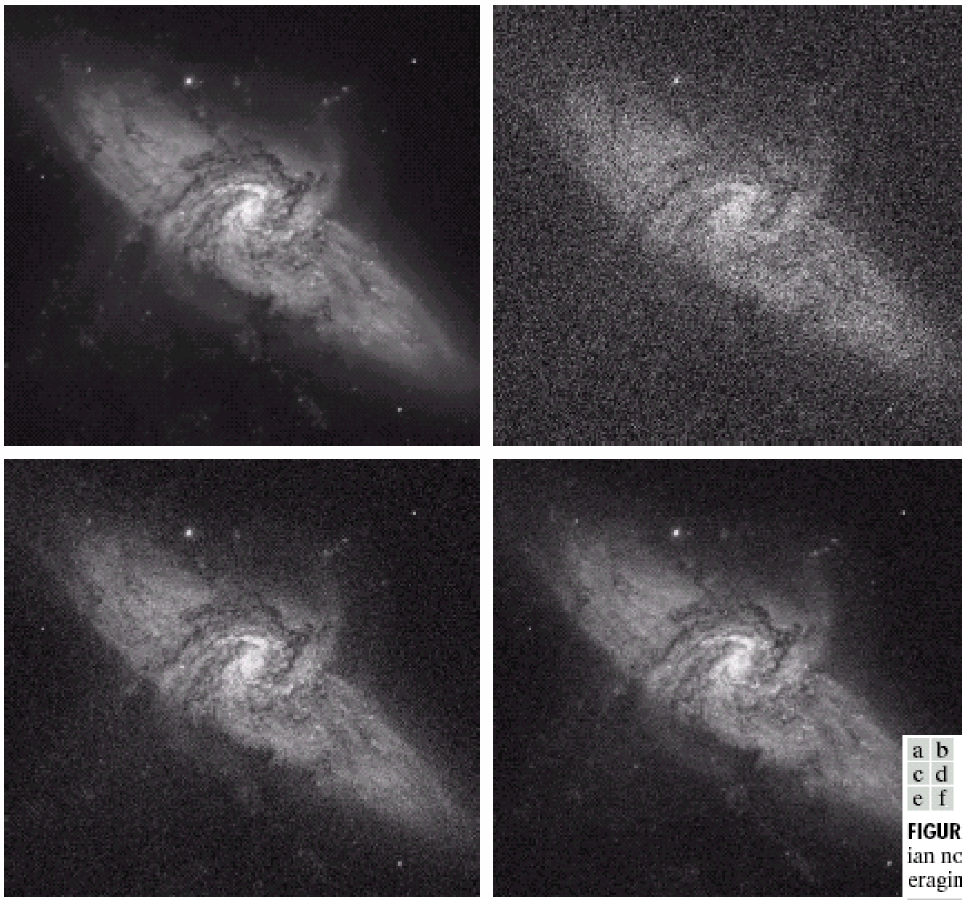


Image Addition

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
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Example: Background Subtraction

- Image arithmetic is simple and powerful.

Is there a person here? Where?

Background Subtraction

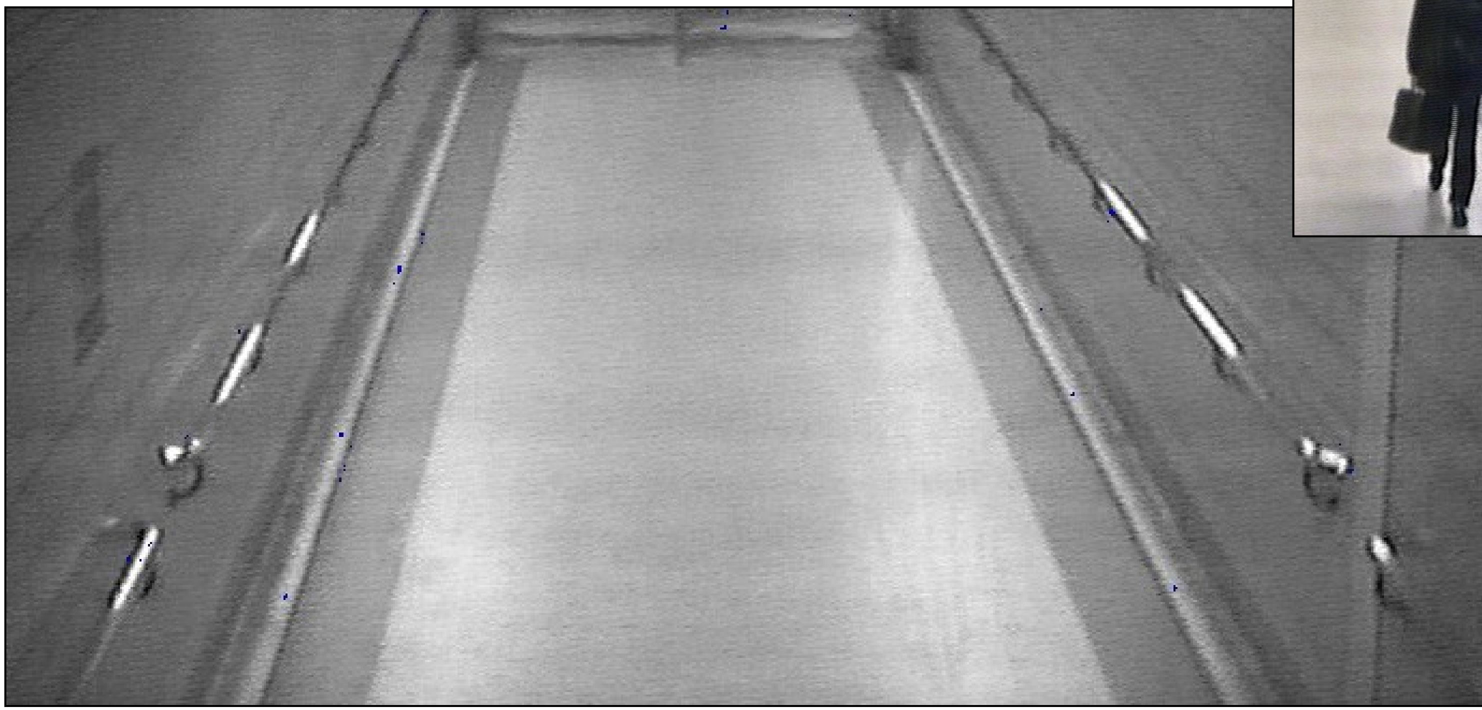
- Remember: We can only see numbers!

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

- 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.