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Digital Image Processing

Image enhancement – Histogram Processing

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Based on slides from:Brian Mac Namee

Image Representation

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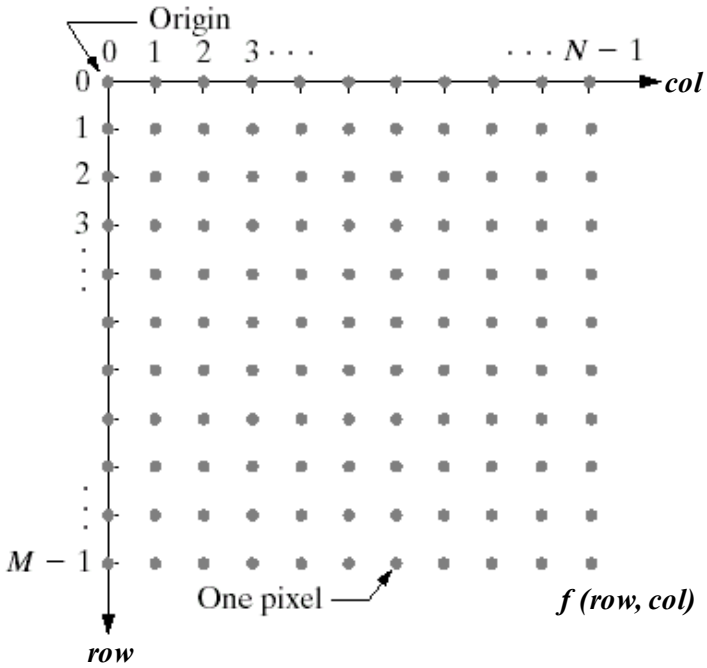
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

A digital image is composed of M rows and N columns of pixels each storing a value

Pixel values are most often grey levels in the range 0-255(black-white)

For many of the image processing operations in this lecture grey levels are assumed to be given in the range [0.0, 1.0]



Contents

Over the next few lectures we will look at image enhancement techniques working in the spatial domain:

- What is image enhancement?
- Different kinds of image enhancement
- Histogram processing
- Point processing
- Neighbourhood operations

What Is Image Enhancement?

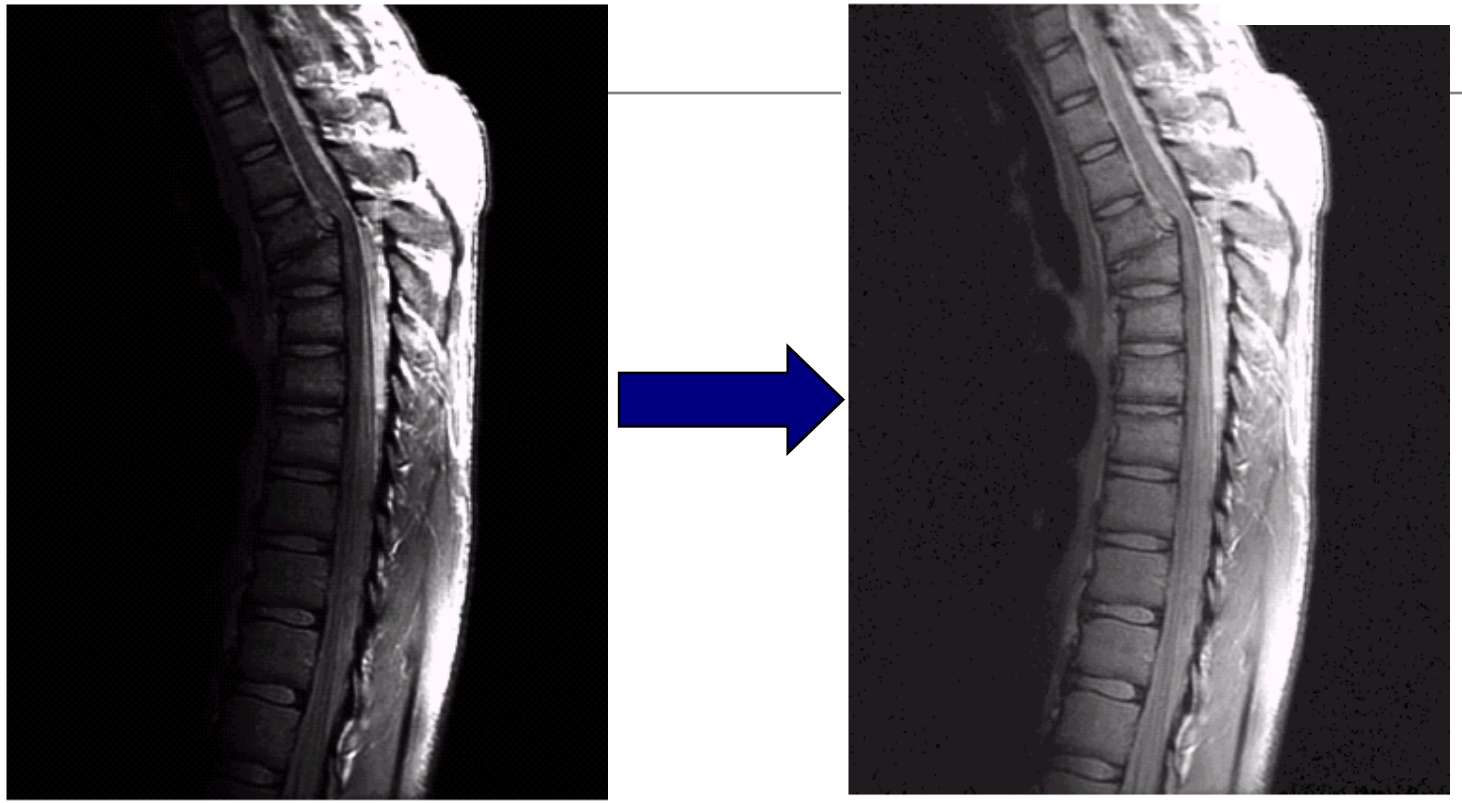
Image enhancement is the process of making images more useful

The reasons for doing this include:

- Highlighting interesting detail in images
- Removing noise from images
- Making images more visually appealing

The process is application specific

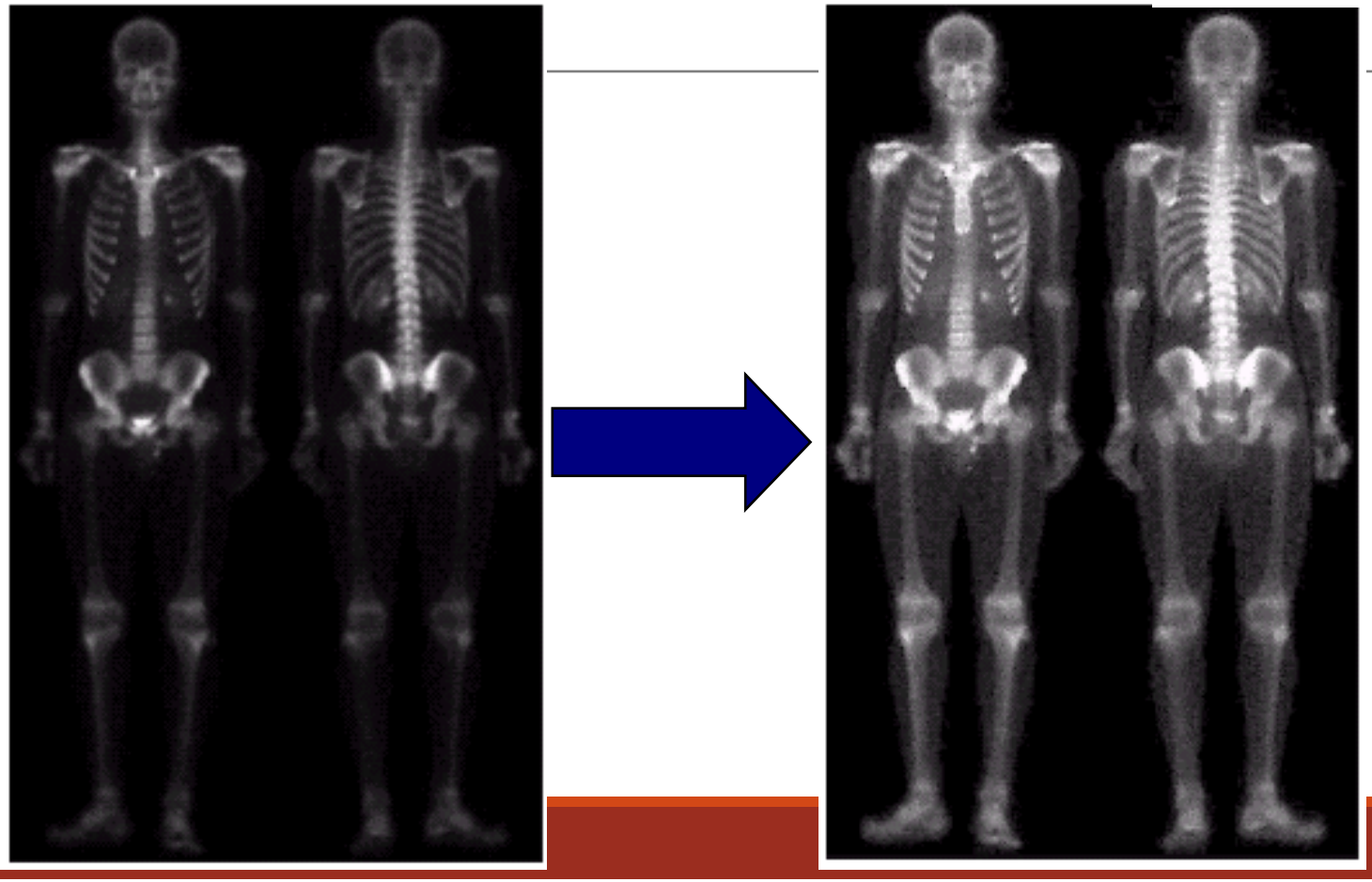
Image Enhancement Examples



Highlighting interesting detail in images

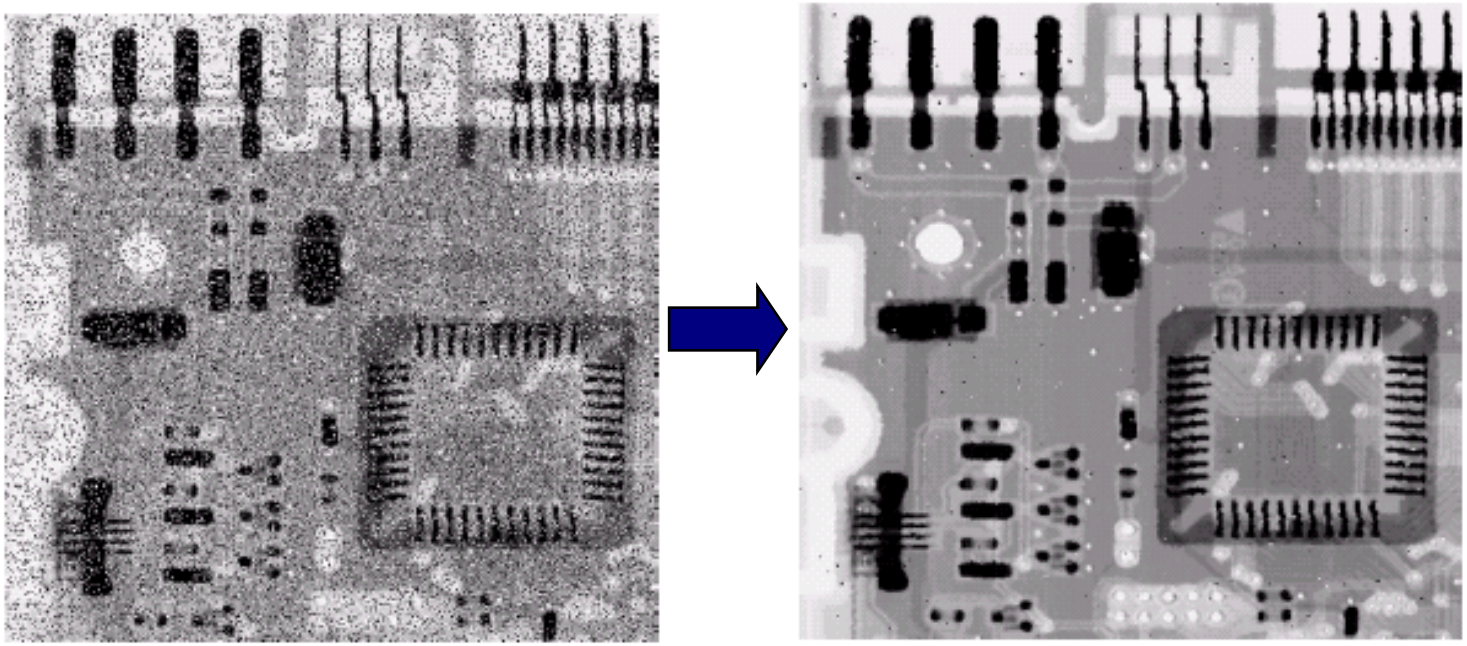
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Enhancement Examples (cont…)



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Enhancement Examples (cont…)



Removing noise from images

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Enhancement Examples (cont…)

Making images more visually appealing

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Spatial & Frequency Domains

There are two broad categories of image enhancement techniques

- Spatial domain techniques
  - Direct manipulation of image pixels
- Frequency domain techniques
  - Manipulation of Fourier transform or wavelet transform of an image

For the moment we will concentrate on techniques that operate in the spatial domain

Image enhancement in the spatial domain

f : input image

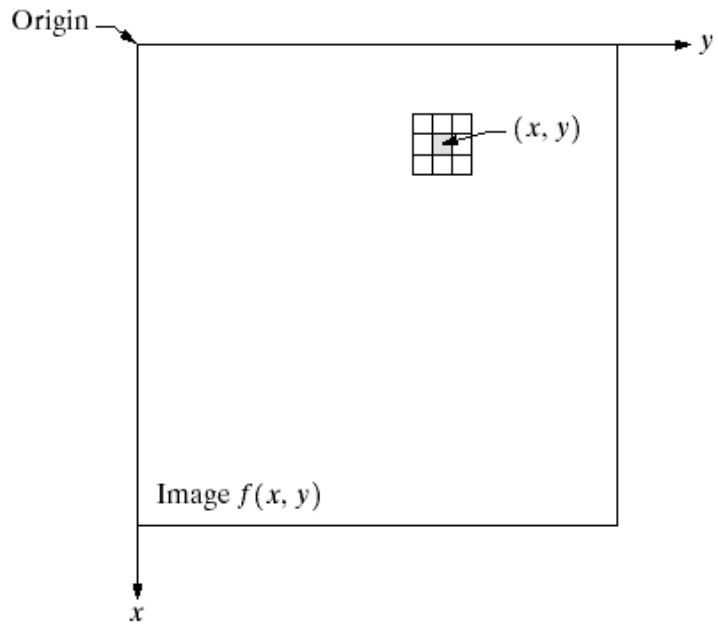
g : output image

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

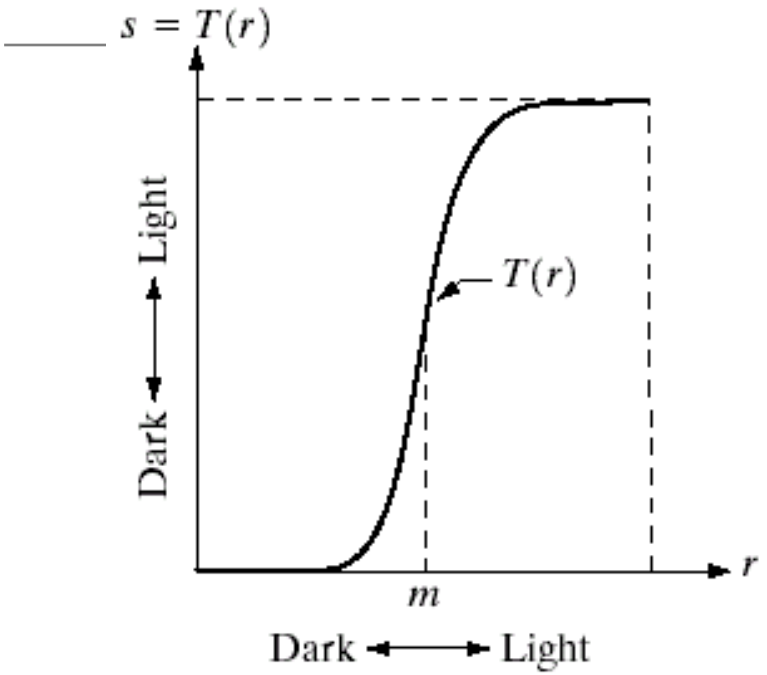
T : operator defined
over a neighborhood of

(x,y)

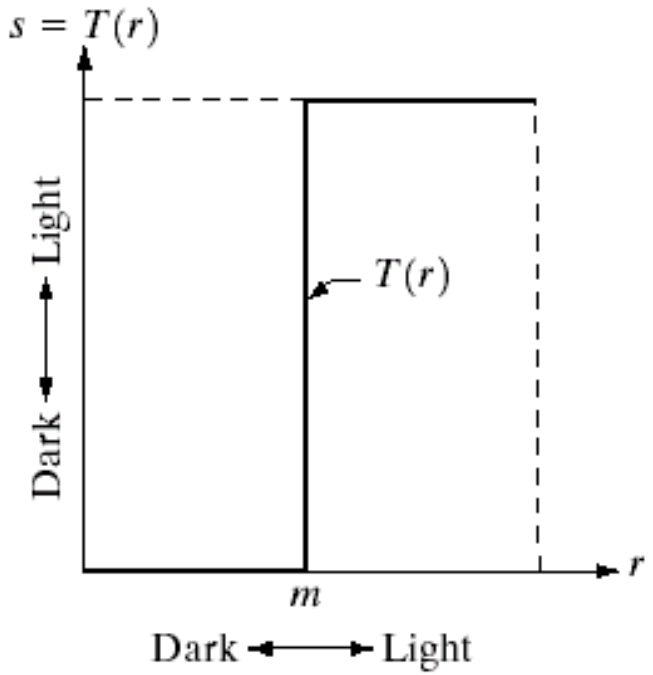
Point processing: neighborhood = 1x1.



Intensity Transformations



Contrast stretching



Thresholding

Intensity Transformations

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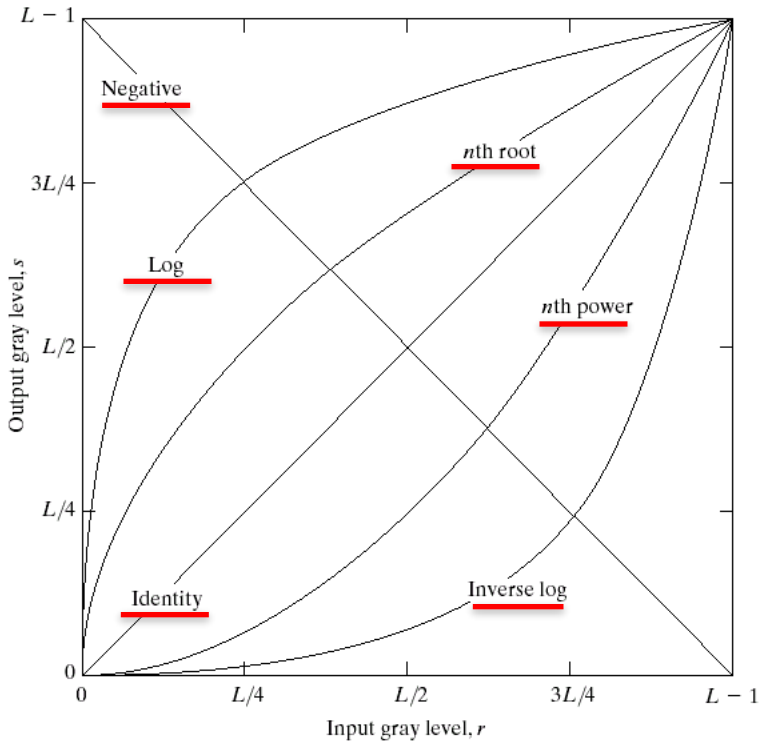
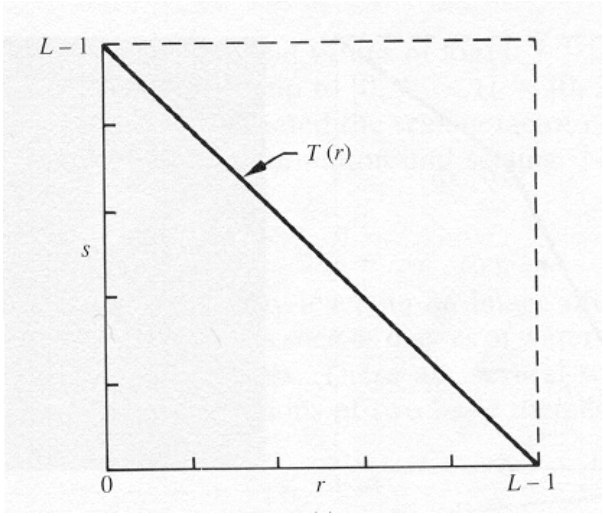
FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



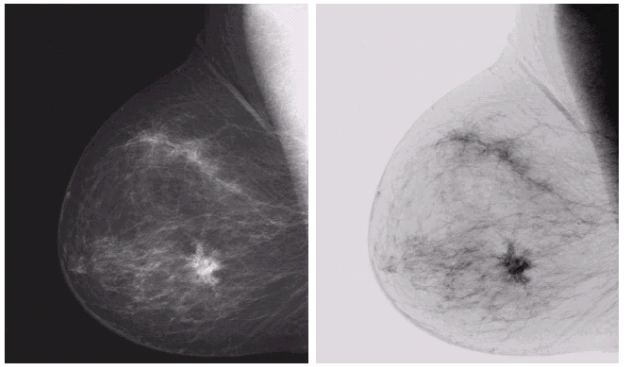
1. Linear
2. Logarithmic
3. Power

Negative Image

Transformation:



Example:



a b

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

$s = T(r)$

$s = (L - 1) - r$

Logarithmic transformations

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Transformation:

$s = T(r)$

$s = c \log(1+ r)$

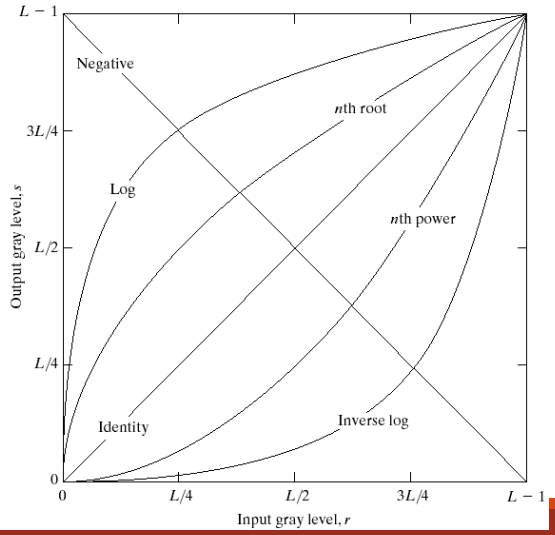
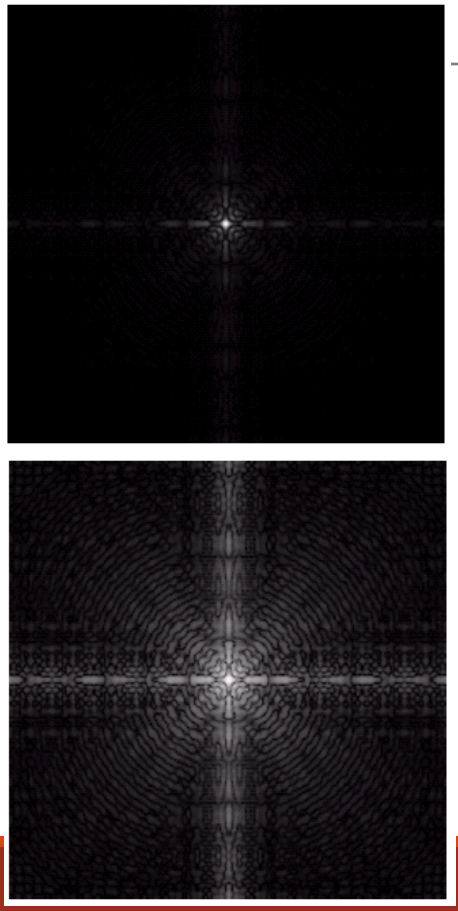


FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.

a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.



Power transformations

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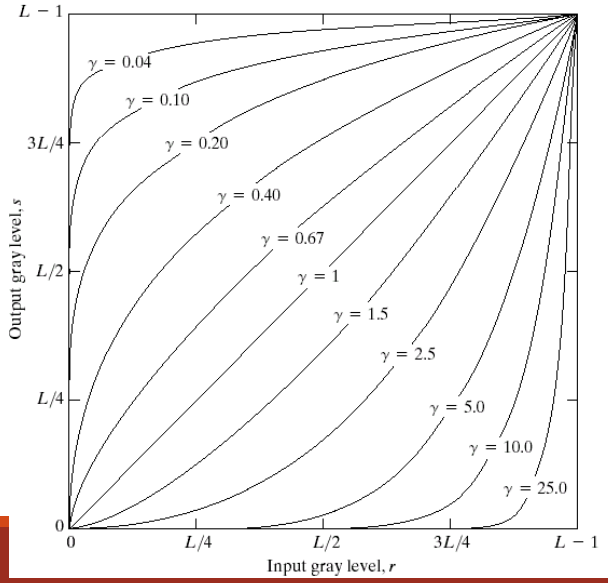
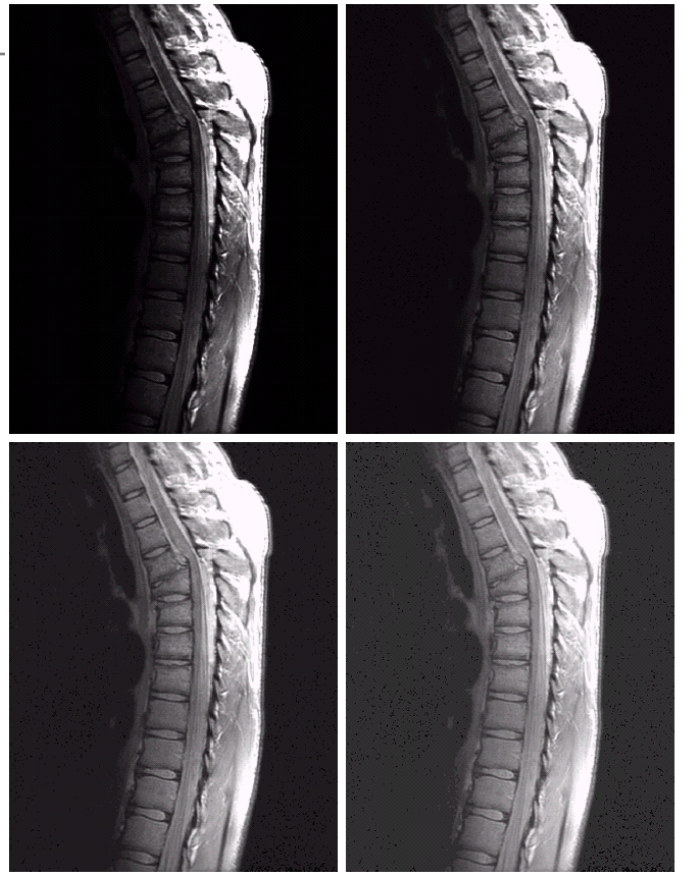
Transformation:

$s = T(r)$

$s = c\,(r + \varepsilon)^{\gamma}$





a b
c d

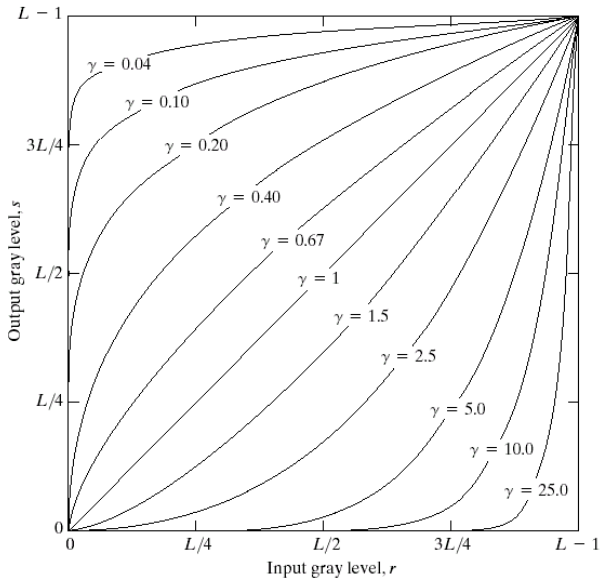
FIGURE 3.8
(a) Magnetic resonance (MR) image of a fractured human spine.
(b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4$, and 0.3, respectively. (Original image for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Power transformations

Transformation:

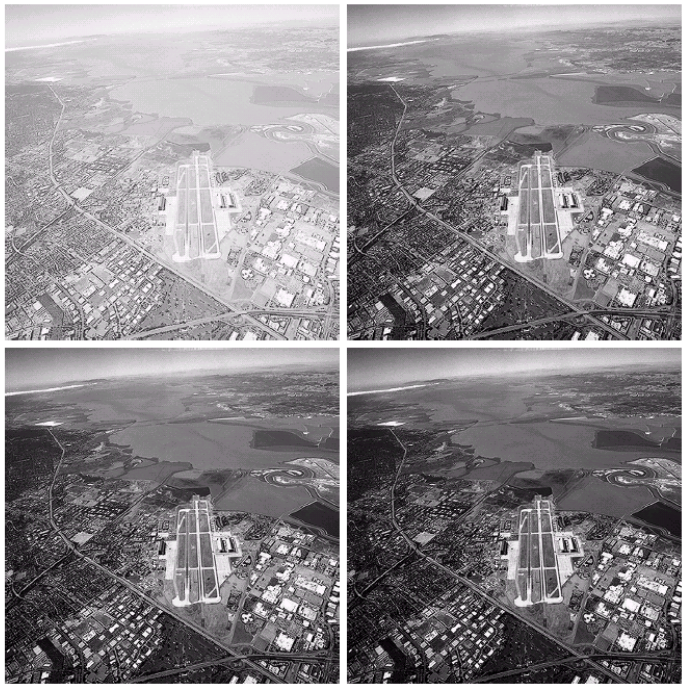
$$s = T(r)$$

$$s = c\,(r + \varepsilon)^{\gamma}$$

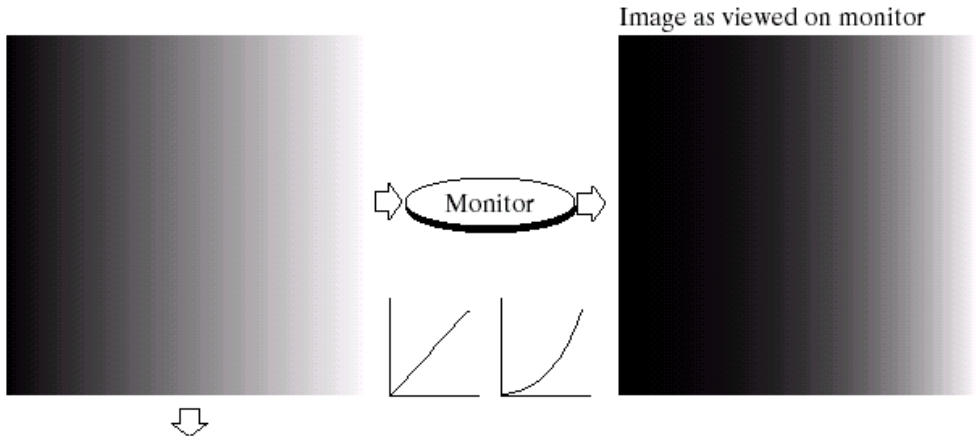


a b
c d

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively. (Original image for this example courtesy of NASA.)



Gamma correction



a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image. (b) Response of monitor to linear wedge. (c) Gamma-corrected wedge. (d) Output of monitor.

Many display devices respond according to a power law transform.

The displayed image doesn't look right!

Gamma correction

a b
c d

FIGURE 3.7
(a) Linear-wedge gray-scale image. (b) Response of monitor to linear wedge. (c) Gamma-corrected wedge. (d) Output of monitor.

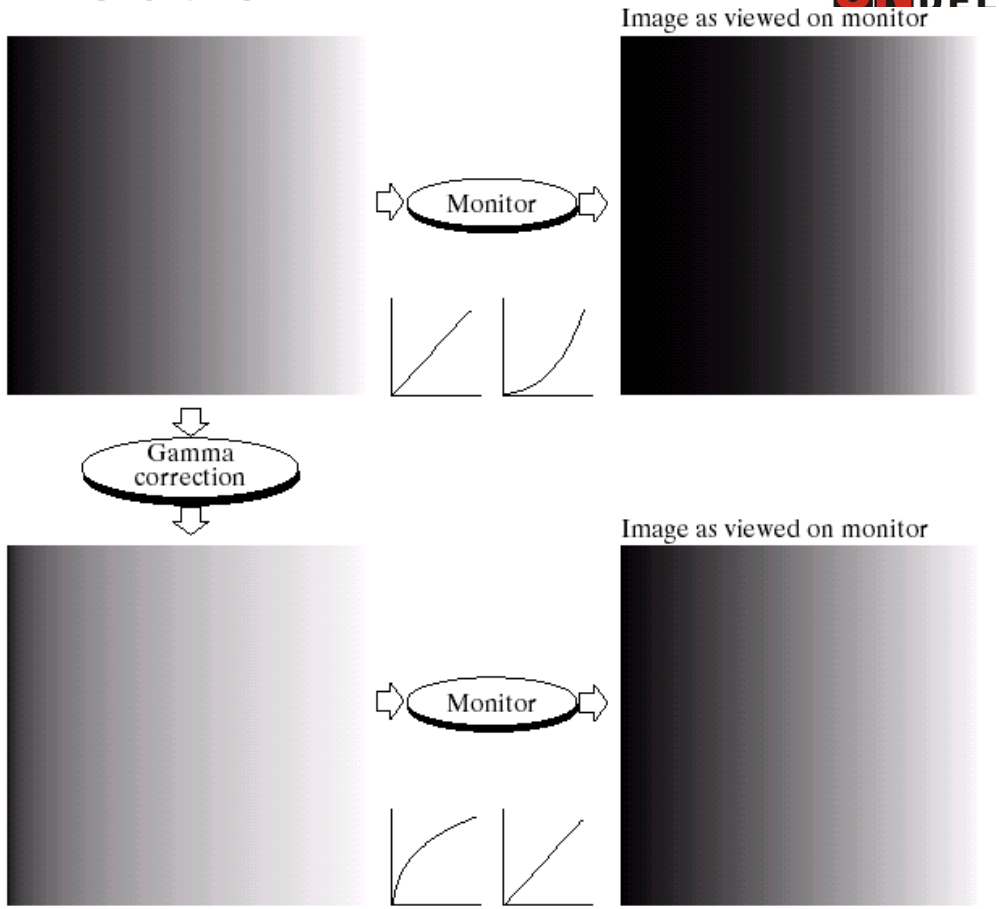
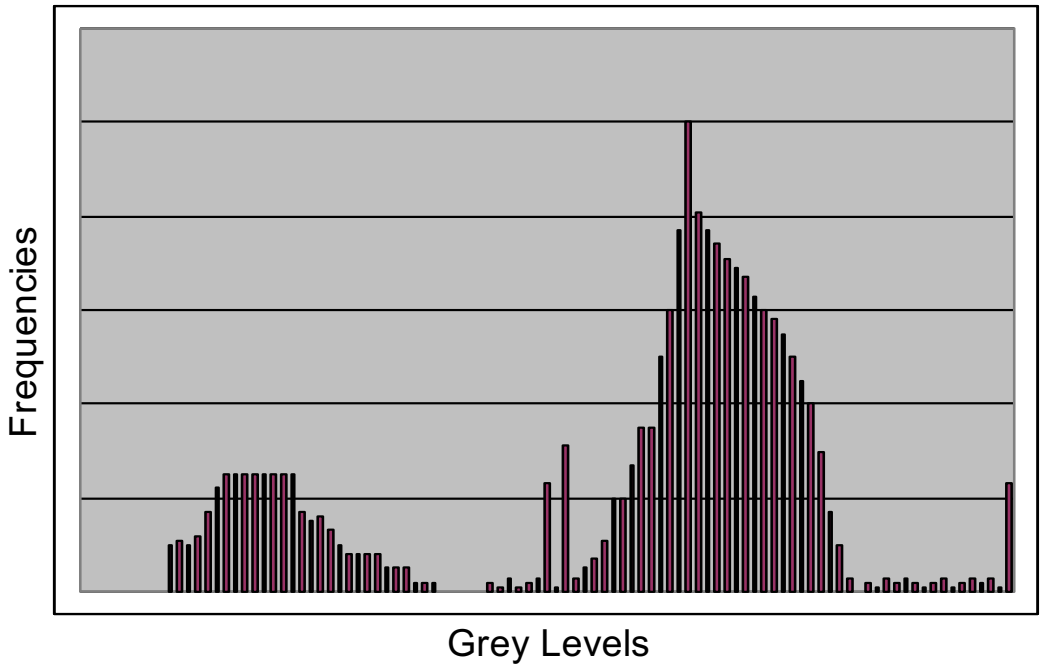


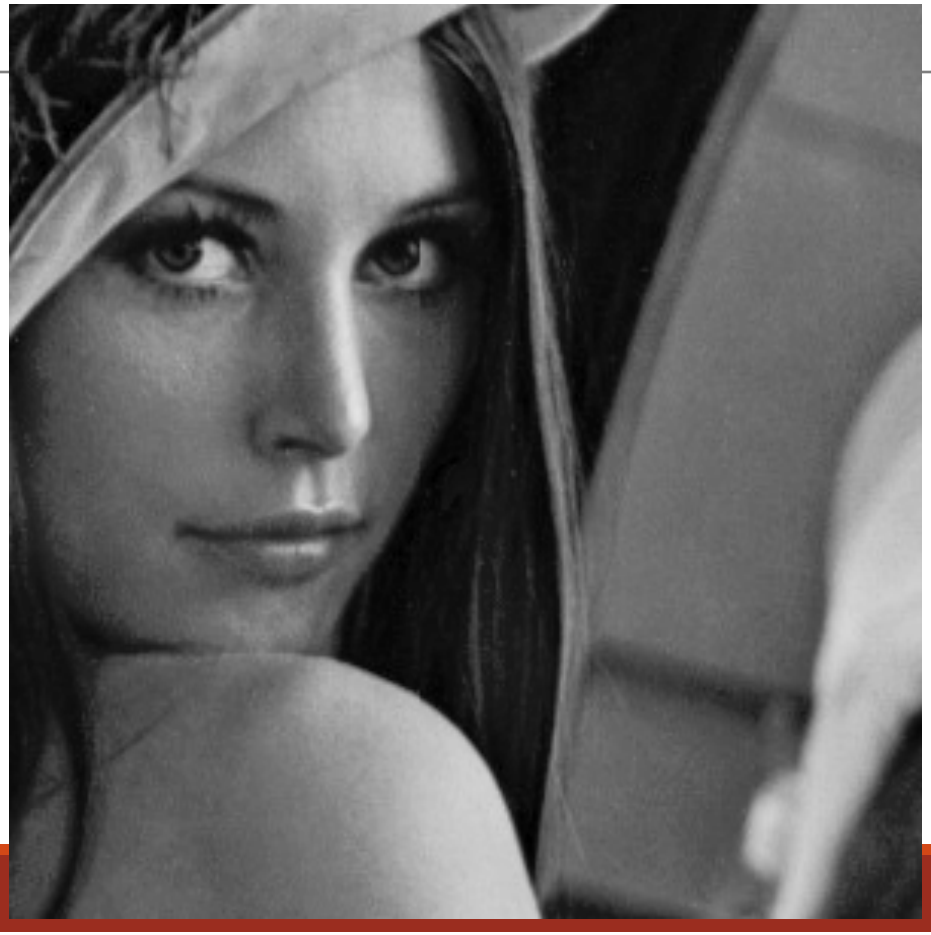
Image Histograms

The histogram of an image shows us the distribution of grey levels in the image

Massively useful in image processing, especially in segmentation



Histogram Examples



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples (cont…)

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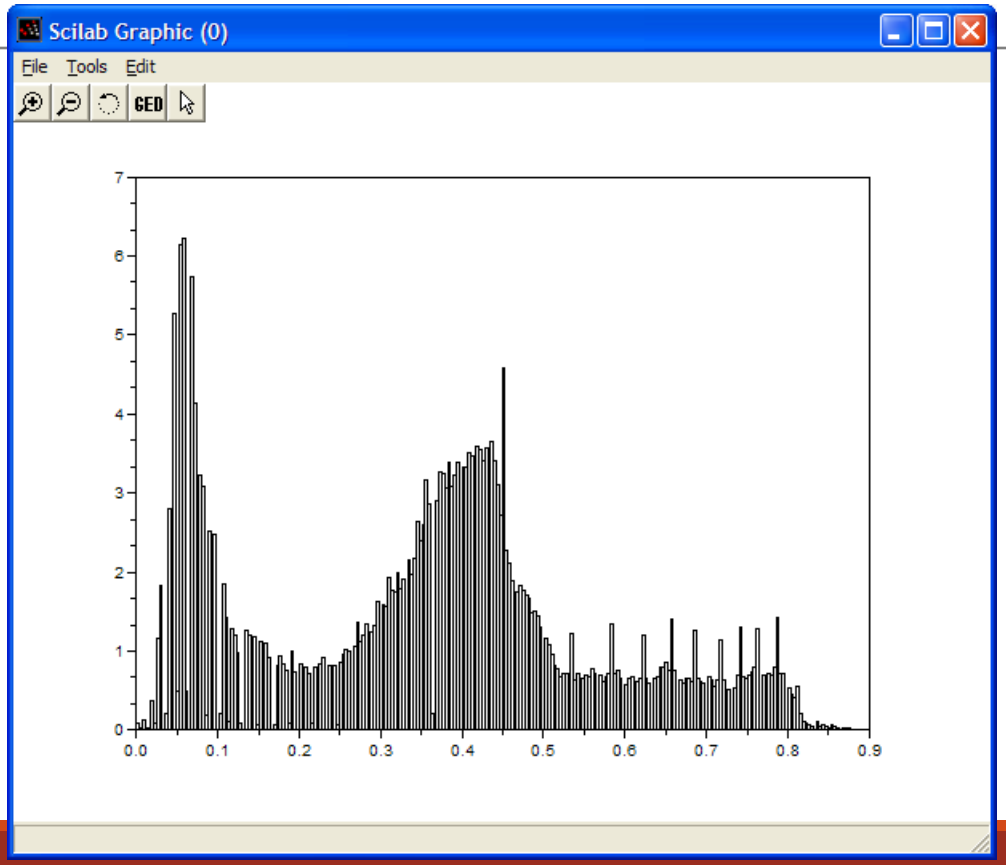
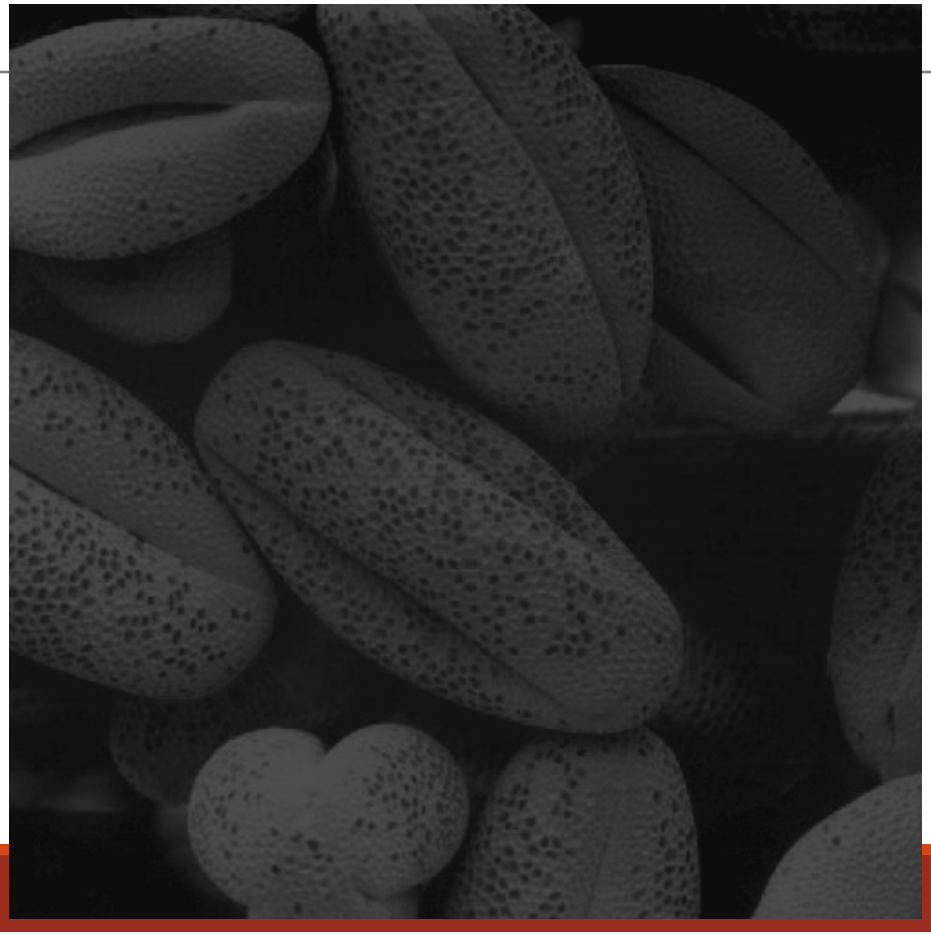
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



Histogram Examples (cont…)



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples (cont…)

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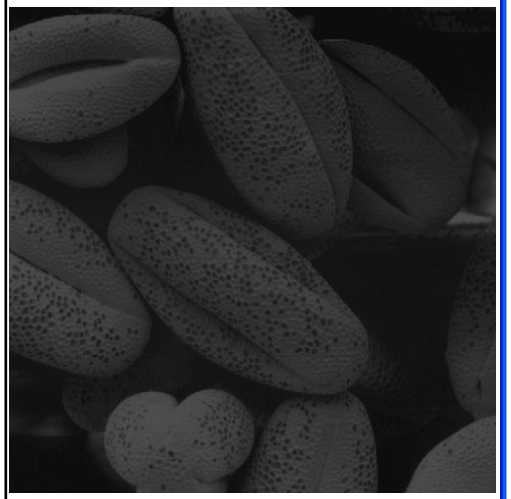
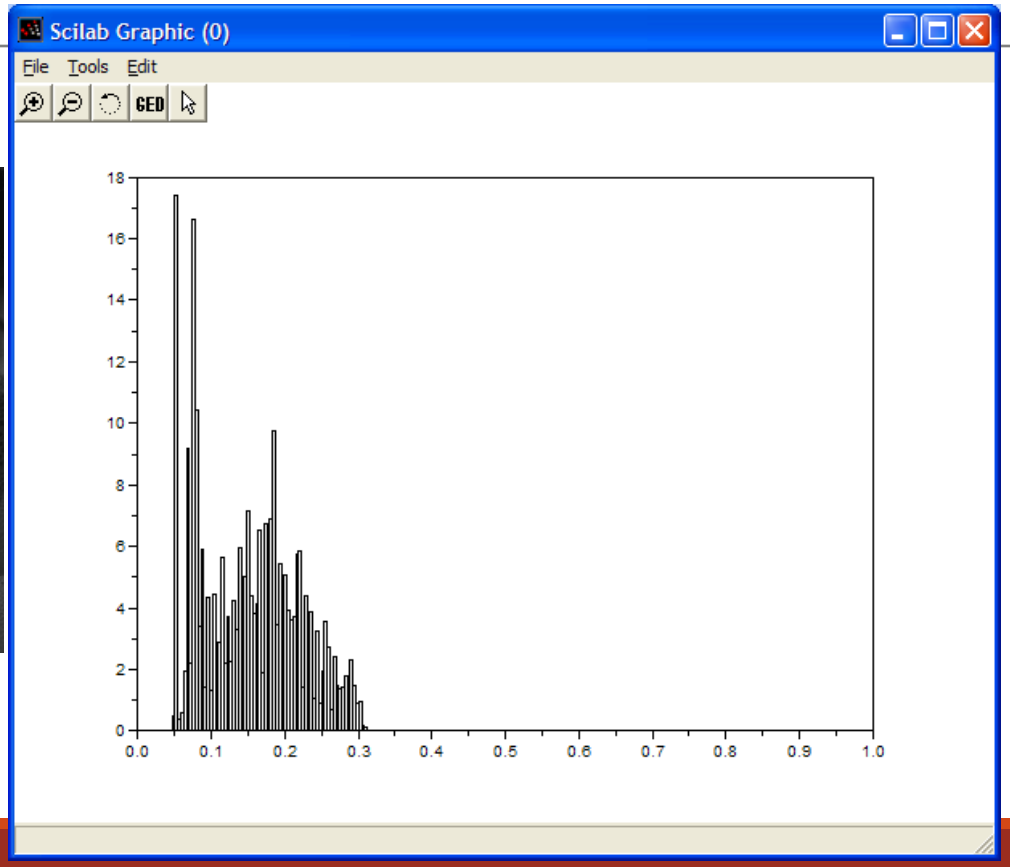
Images taken from Gonzalez & Woods, Digital Image Processing (2002)





Histogram Examples (cont…)

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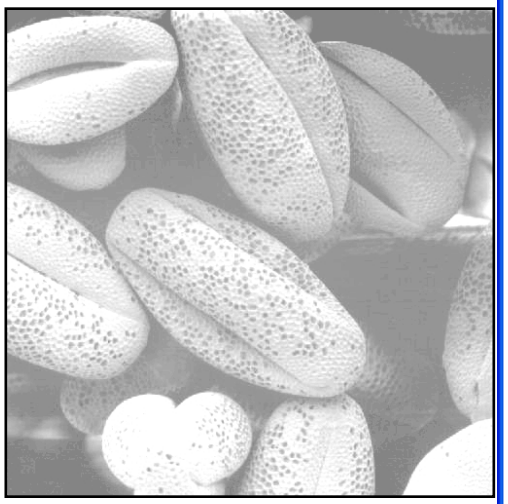
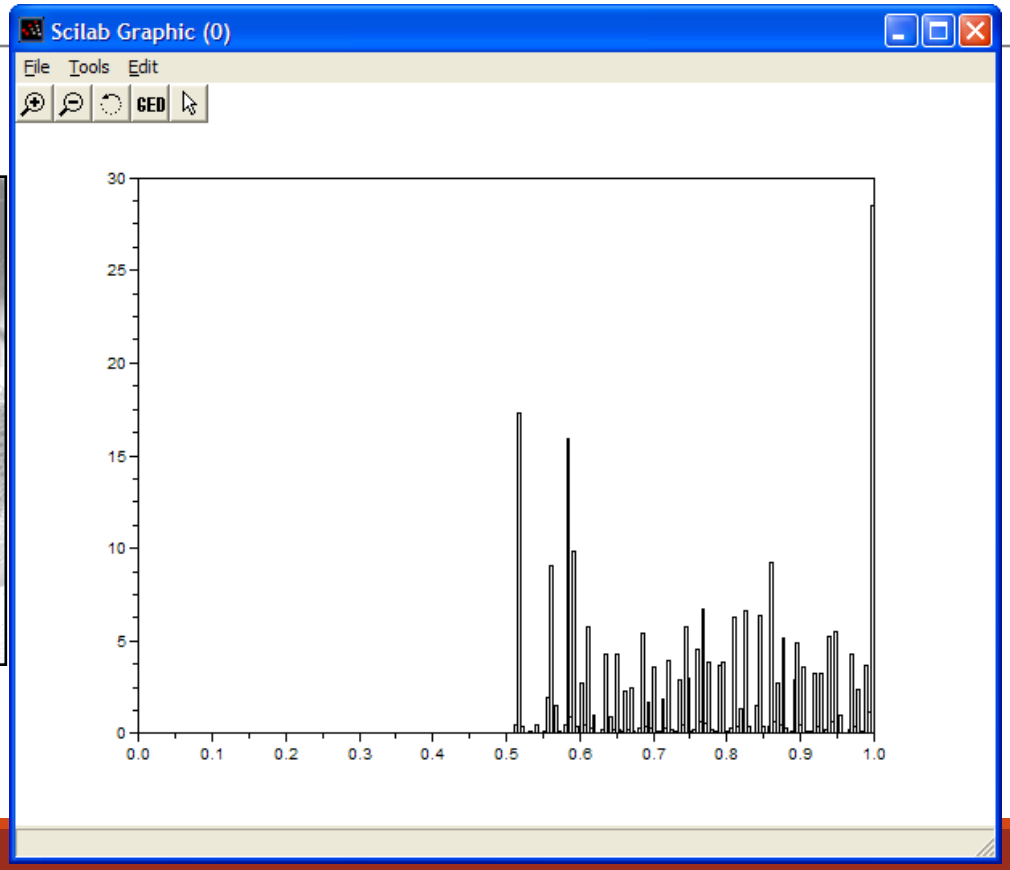
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

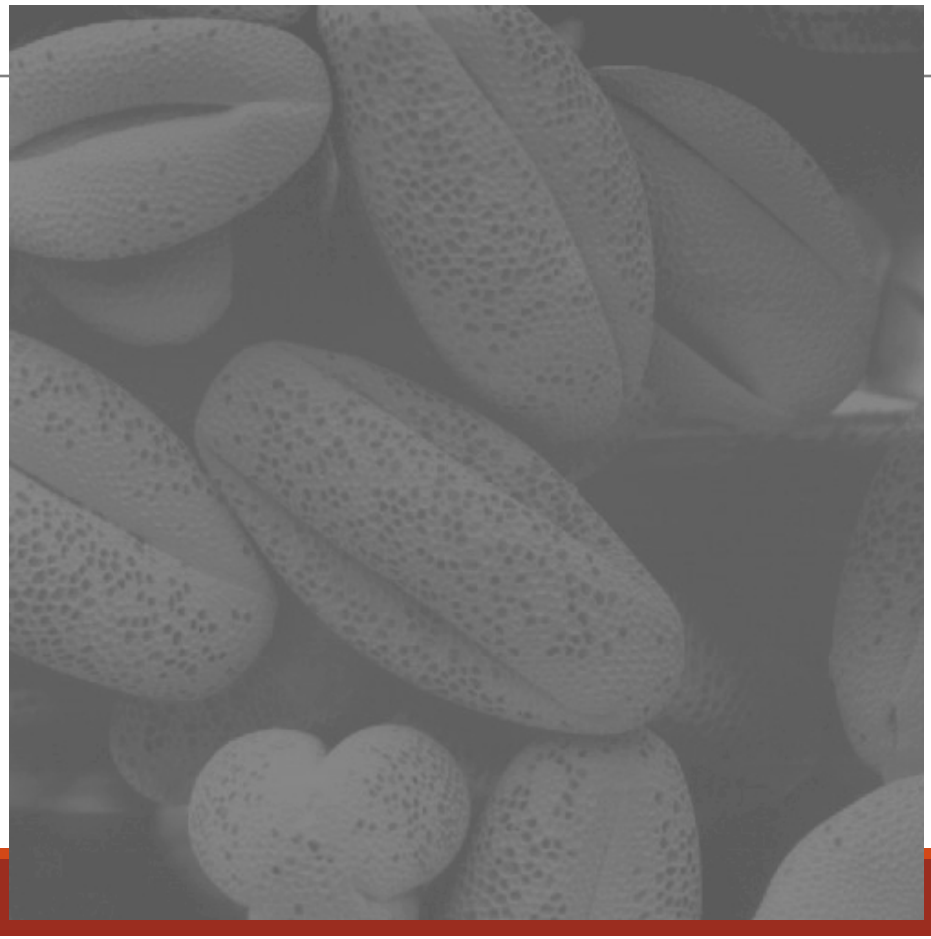
Histogram Examples (cont…)





Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples (cont…)



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples (cont…)

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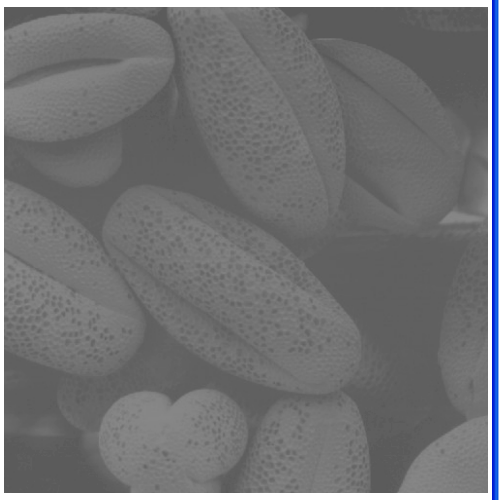
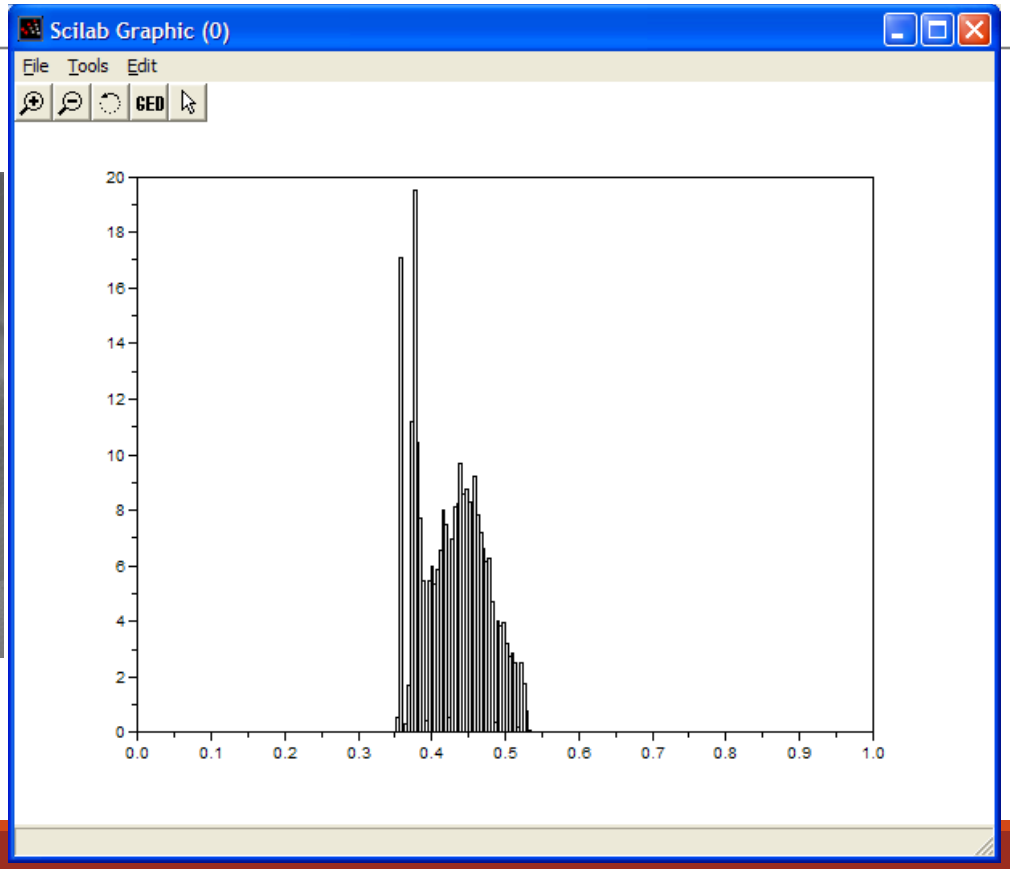
Images taken from Gonzalez & Woods, Digital Image Processing (2002)





Histogram Examples (cont…)

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples (cont…)

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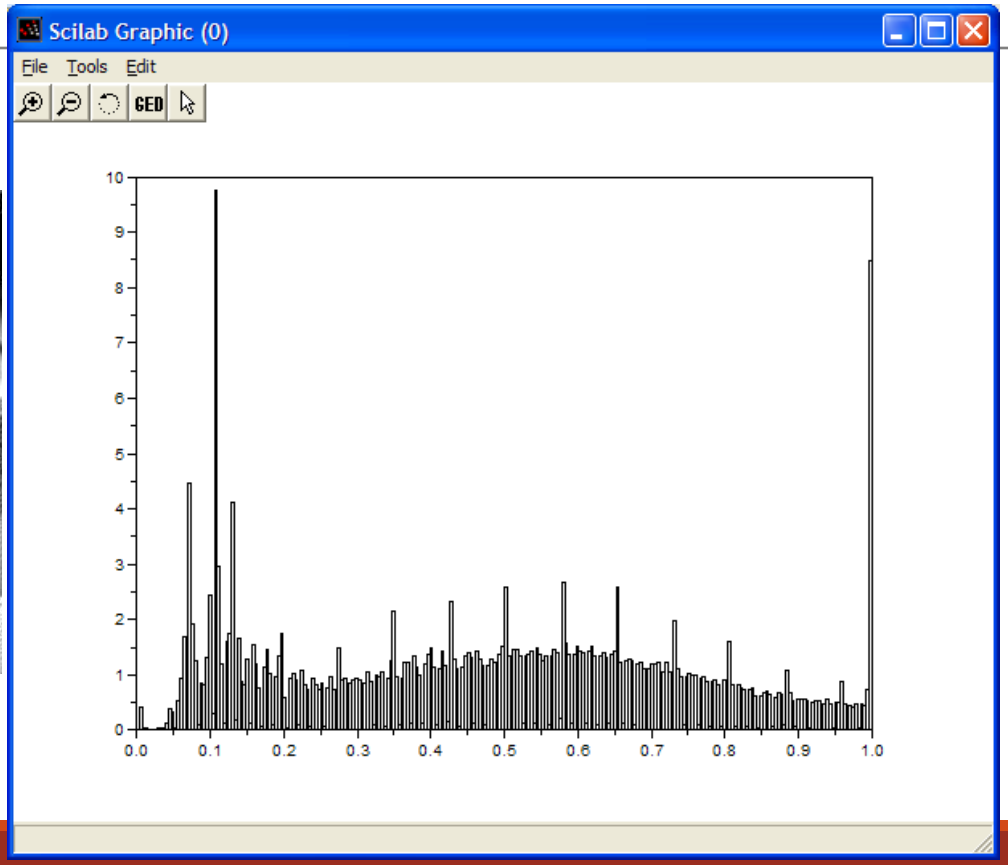
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



Histogram Examples (cont…)

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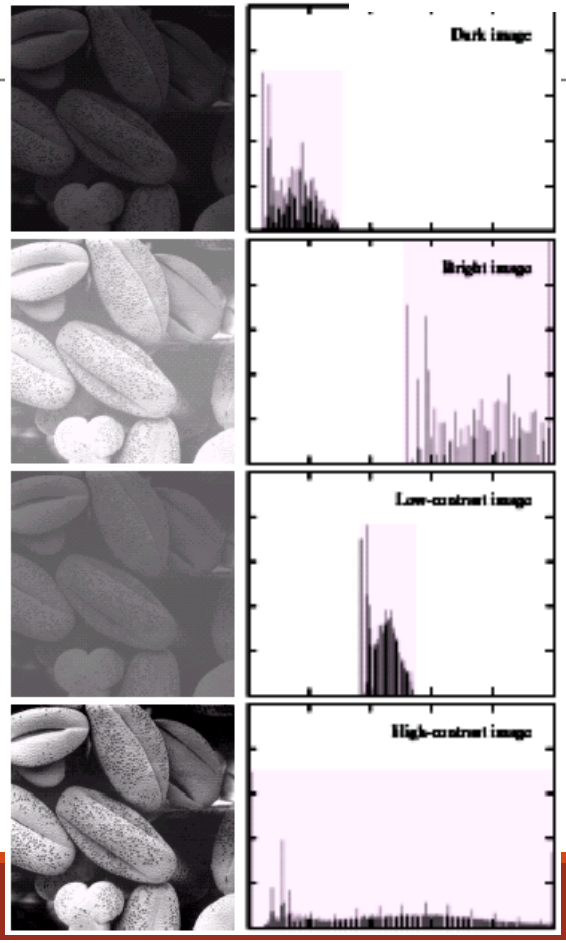
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

A selection of images and their histograms

Notice the relationships between the images and their histograms

Note that the high contrast image has the most evenly spaced histogram



Contrast Stretching

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We can fix images that have poor contrast by applying a pretty simple contrast specification

The interesting part is how do we decide on this transformation function?

Histogram Equalisation

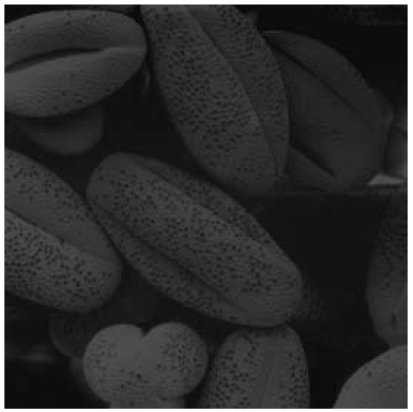
Spreading out the frequencies in an image (or equalising the image) is a simple way to improve dark or washed out images

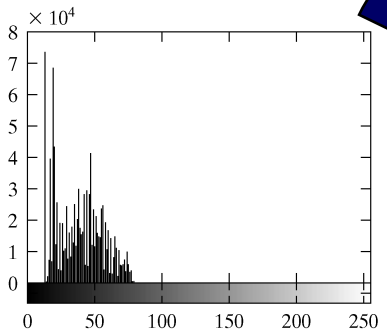
The formula for histogram equalisation is given where

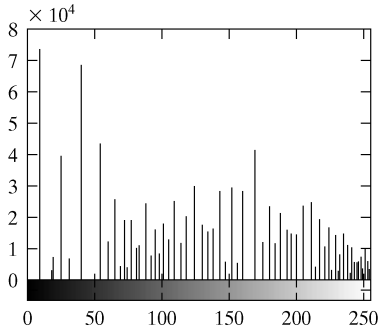
- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)
- n_j: the frequency of intensity j
- n: the sum of all frequencies

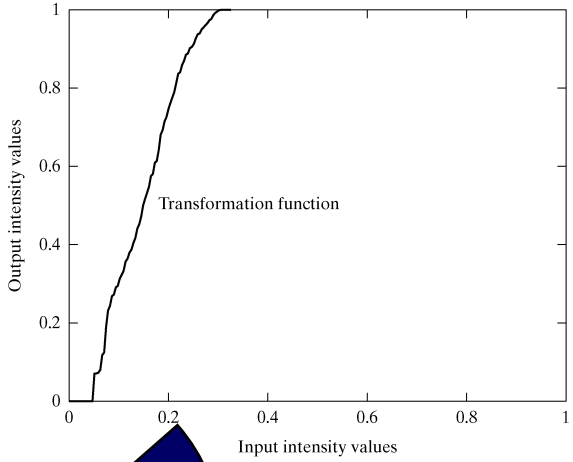
$$s_k = T(r_k)$$
$$= \sum_{j=1}^{k} p_r(r_j)$$
$$= \sum_{j=1}^{k} \frac{n_j}{n}$$

Equalisation Transformation Function

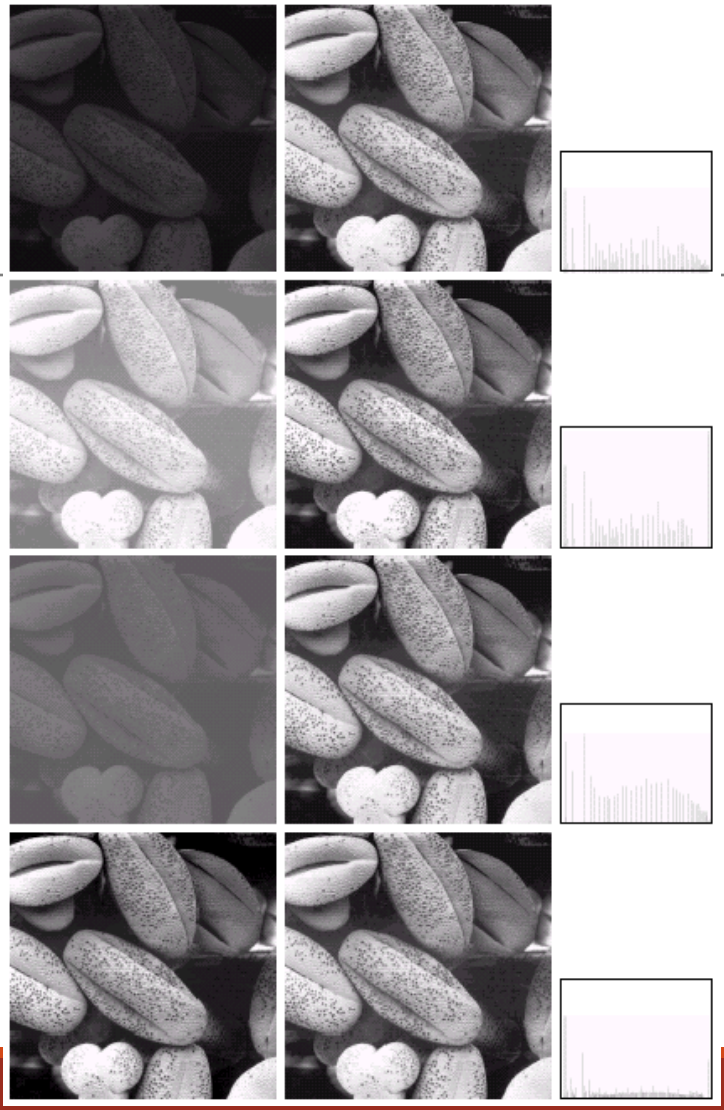


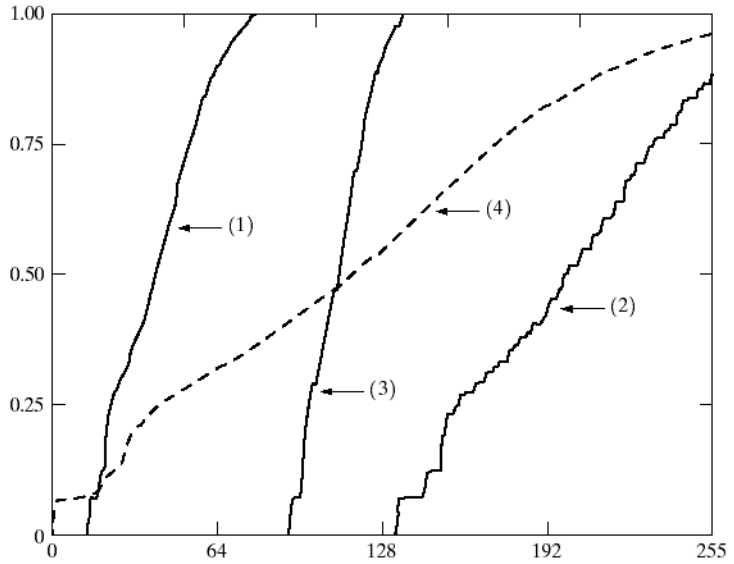






Images taken from Gonzalez & Woods, Digital Image Processing (2002)




1.00
0.75
0.50
0.25
0
0
64
128
192
255
(1)
(2)
(3)
(4)

Summary

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We have looked at:

- Different kinds of image enhancement
- Point processing
- Histograms
- Histogram equalisation

Next time we will start to look at some neighbourhood operations