Digital Image Processing

Image Enhancement

(Histogram Processing)

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

A Note About Grey Levels

- So far when we have spoken about image grey level values we have said they are in the range [0, 255]
  - Where 0 is black and 255 is white
- There is no reason why we have to use this range
  - The range [0,255] stems from display technologes
- For many of the image processing operations in this lecture grey levels are assumed to be given in the range [0.0, 1.0]

What Is Image Enhancement?

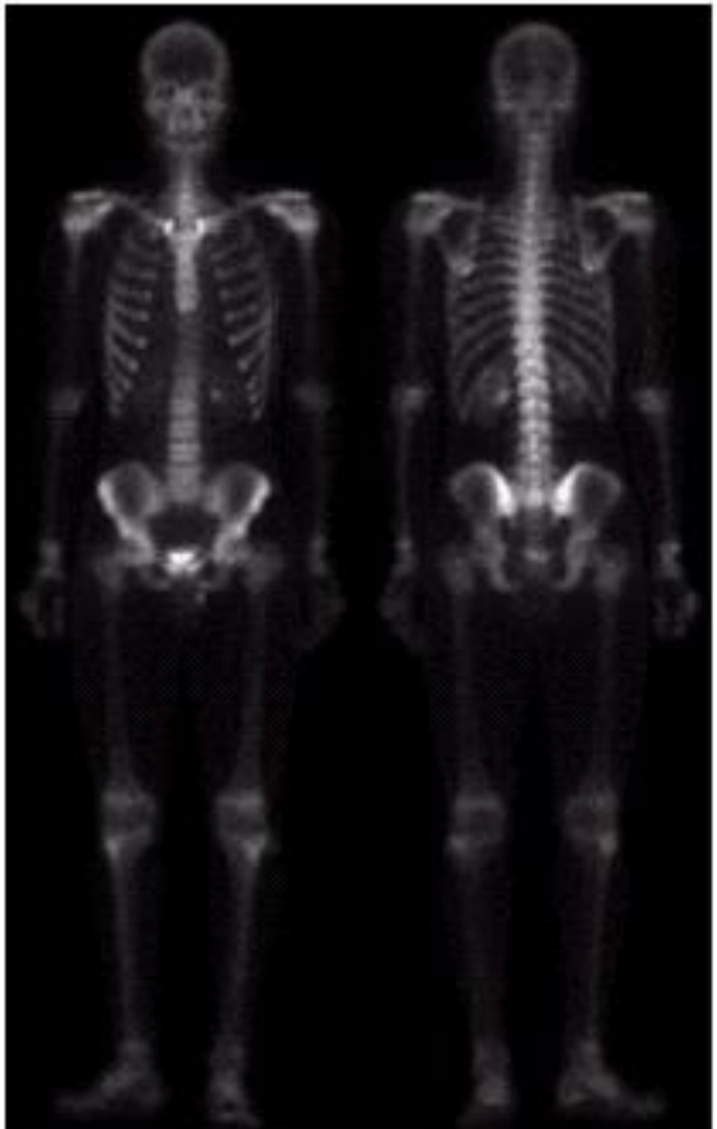
Image enhancement is the process of making images more useful

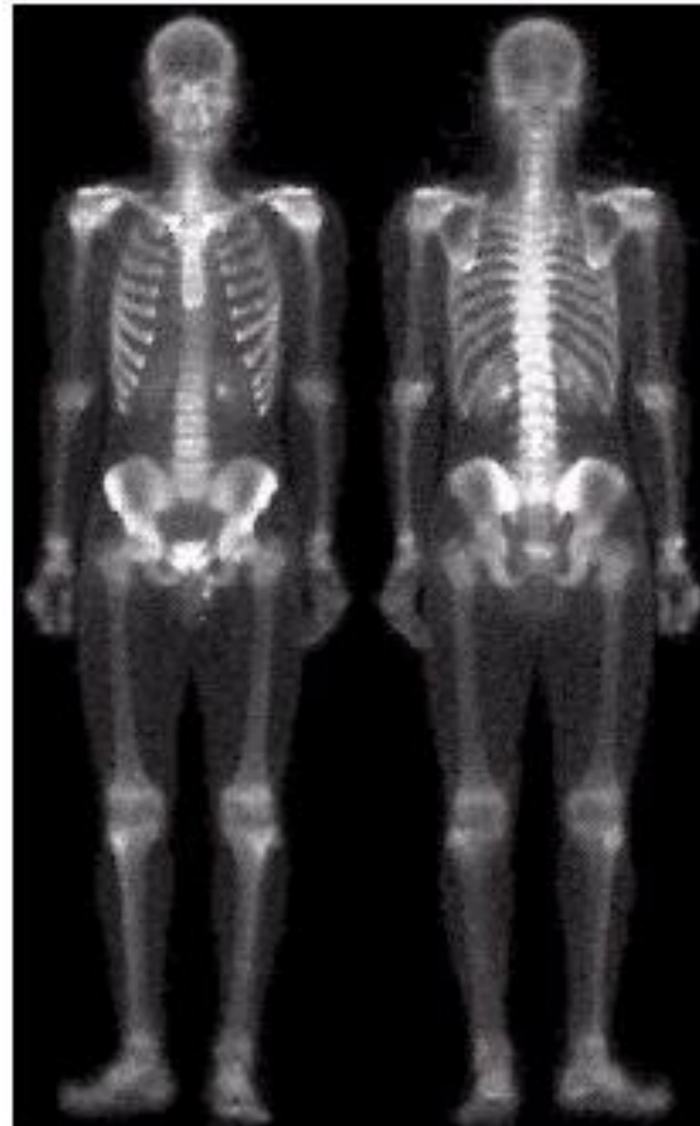
The reasons for doing this include:

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

Image Enhancement Examples

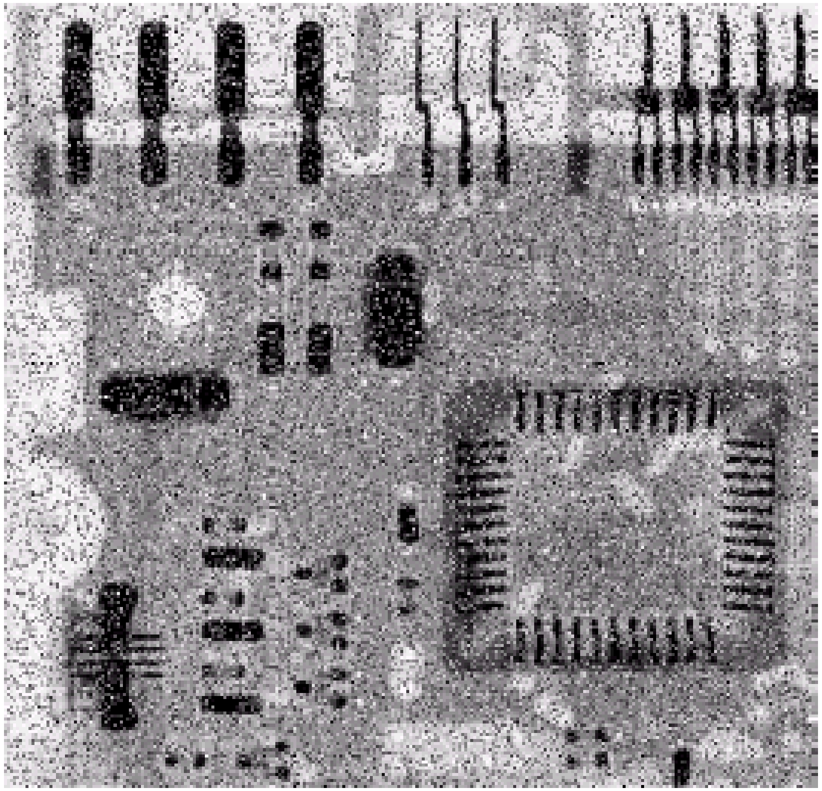
Image Enhancement Examples (cont…)





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

Image Enhancement Examples (cont…)



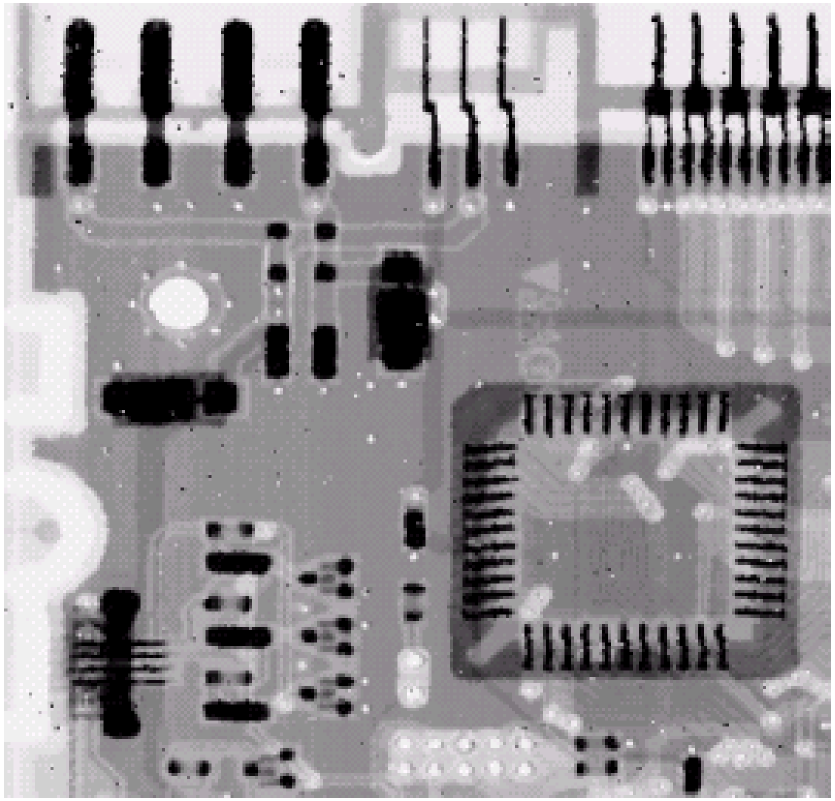


Image Enhancement Examples (cont…)

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

Histogram of an Image

Histogram: the distribution of gray intensity over all pixels in the images

r presents the gray level of a pixel

n presents the number of pixels with intensity *r*

L presents the highest gray level

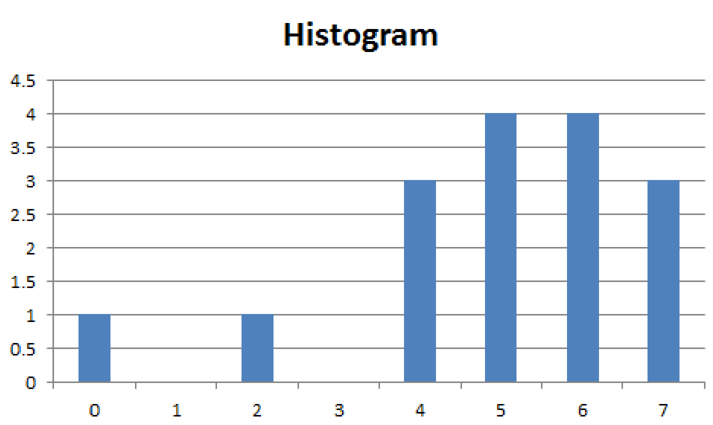
Normalized histogram: Divide its value to total number of pixels

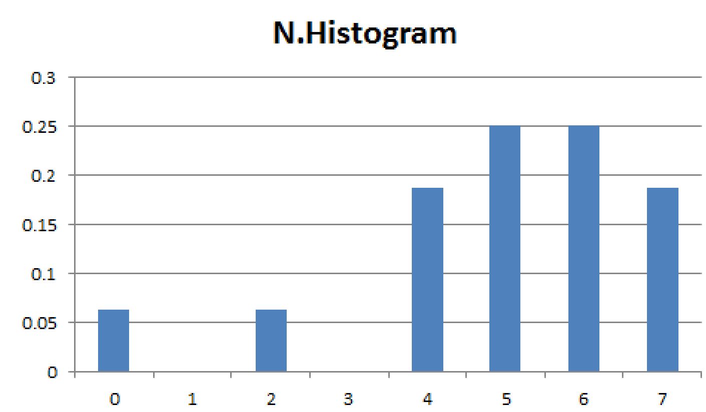
N presents total number of pixels in the image

Histogram Example

2	5	7	6
4	5	4	7
6	5	6	4
0	7	5	6

Intensity	0	1	2	3	4	5	6	7
Histogram	1	0	1	0	3	4	4	3
N.Histogram	0.0625	0	0.0625	0	0.1875	0.25	0.25	0.1875





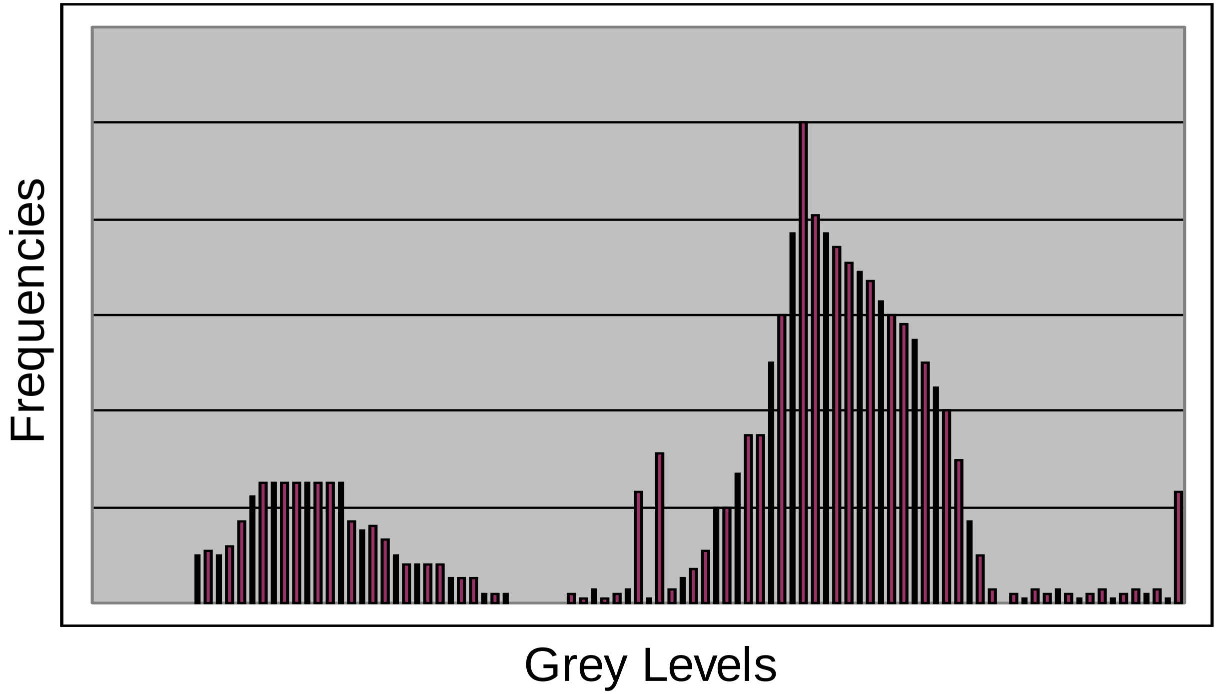
0	2	1	7
3	2	5	2
1	1	7	6
5	0	0	3

3	3	2
1	1	0
2	2	2

Image Histograms

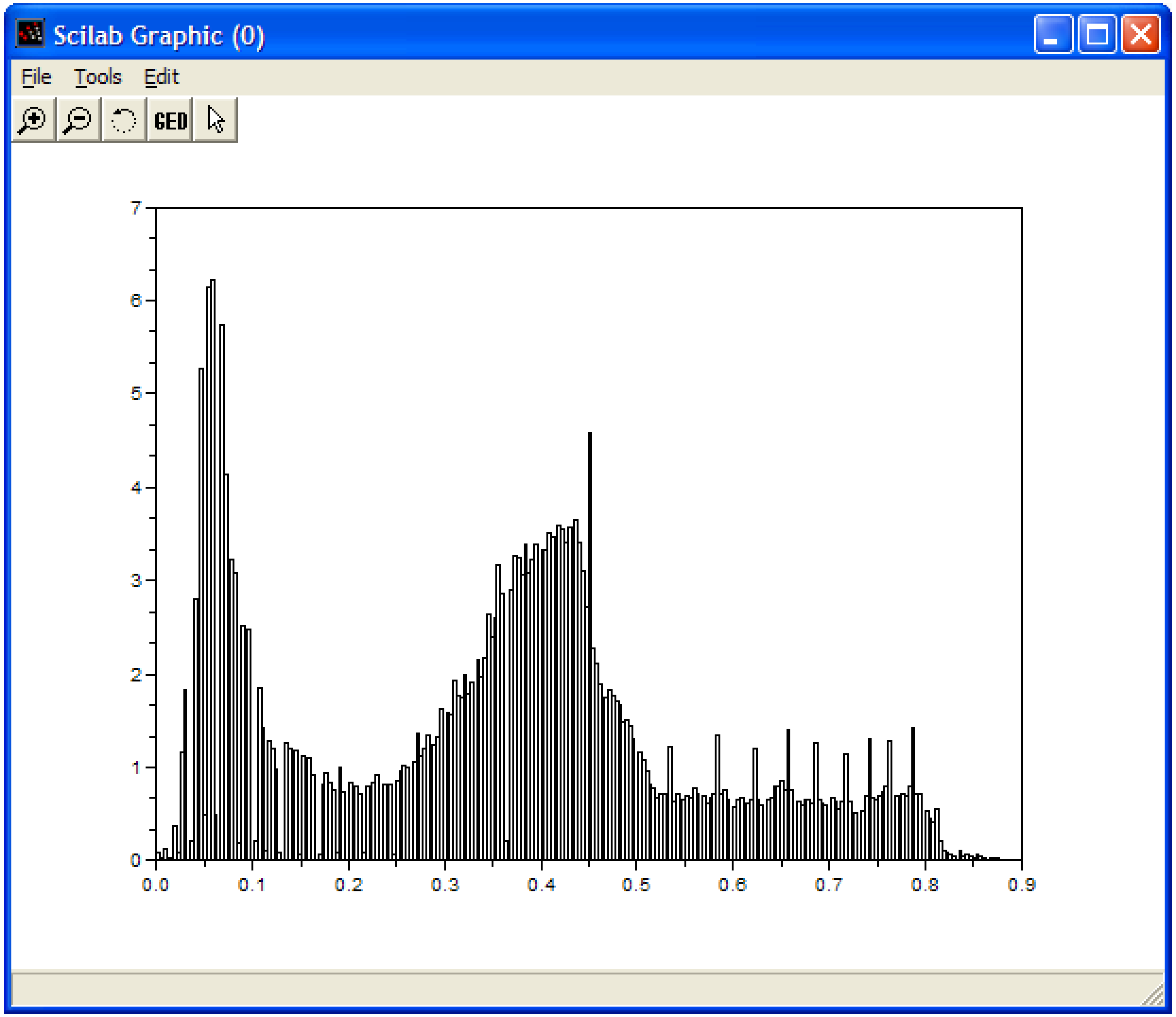
The histogram of an image shows us the distribution of grey levels in the image

Massively useful in image processing, especially in segmentation

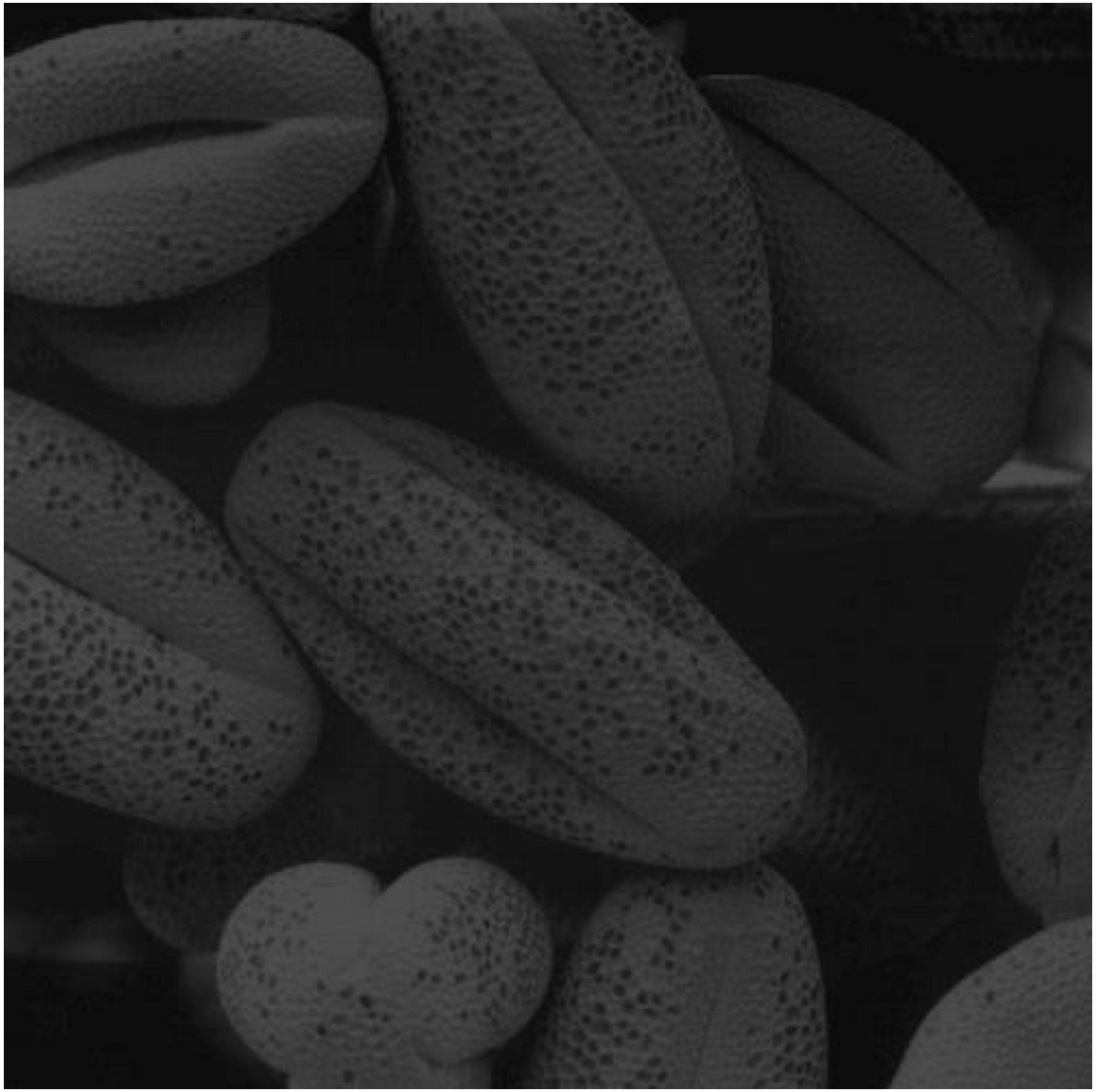


Histogram Examples

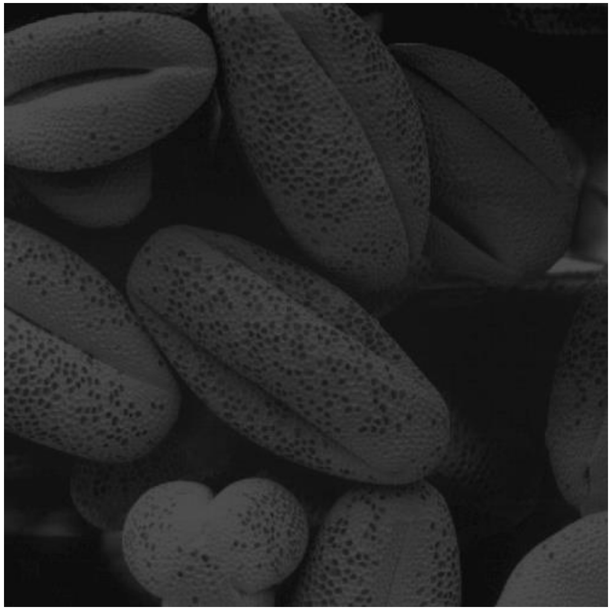
Histogram Examples (cont…)

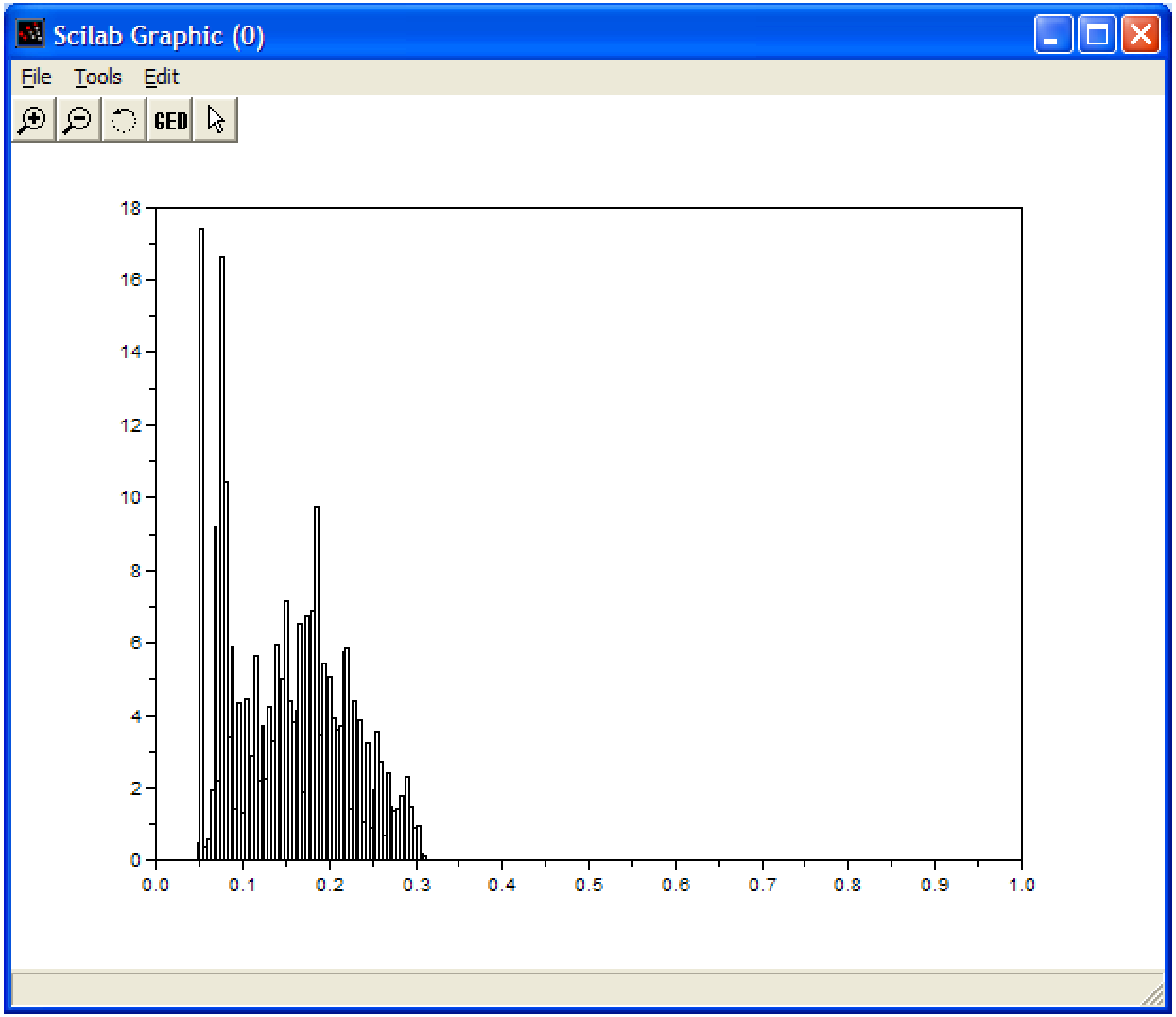


Histogram Examples (cont…)



Histogram Examples (cont…)





Histogram Examples (cont…)

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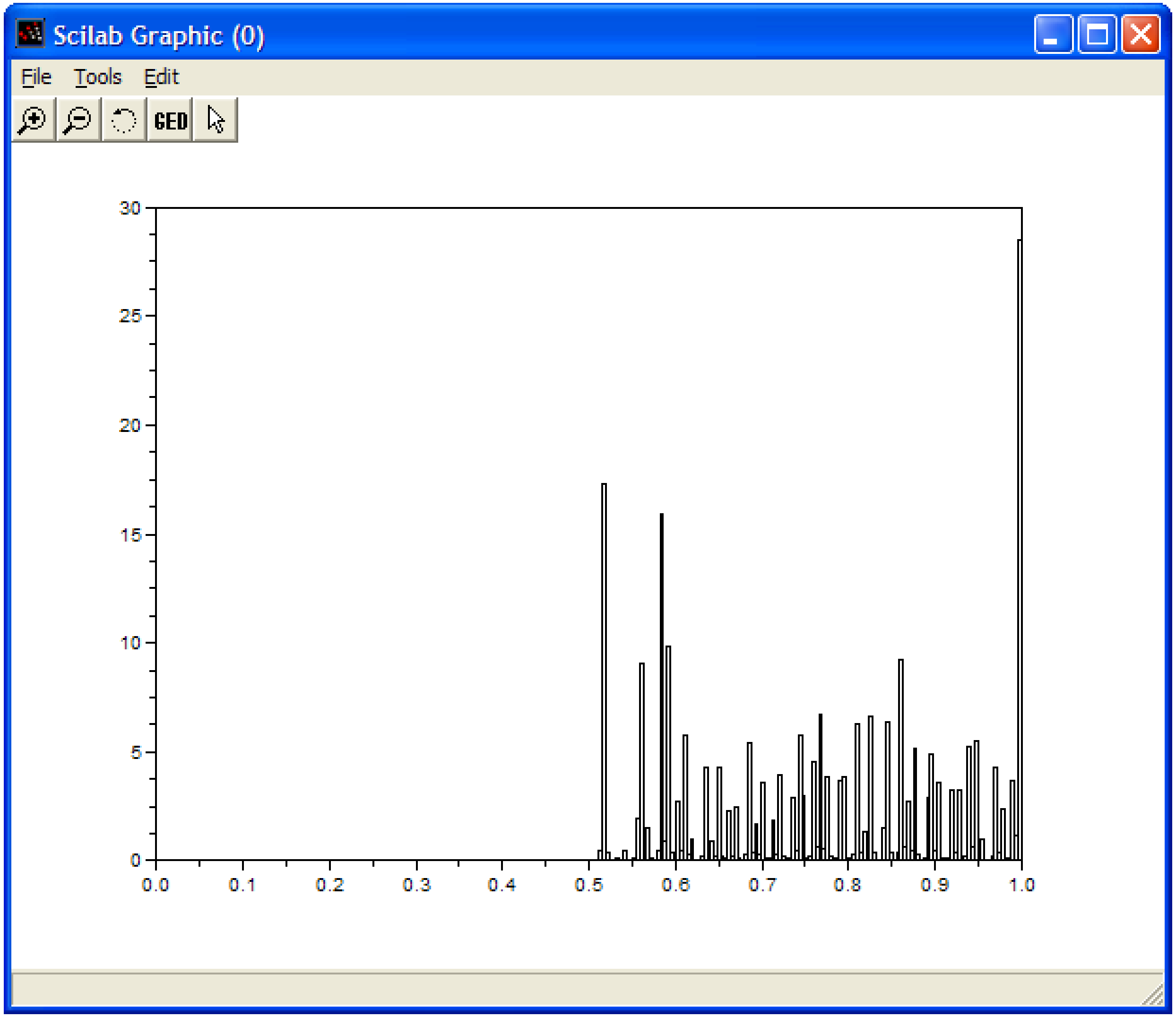
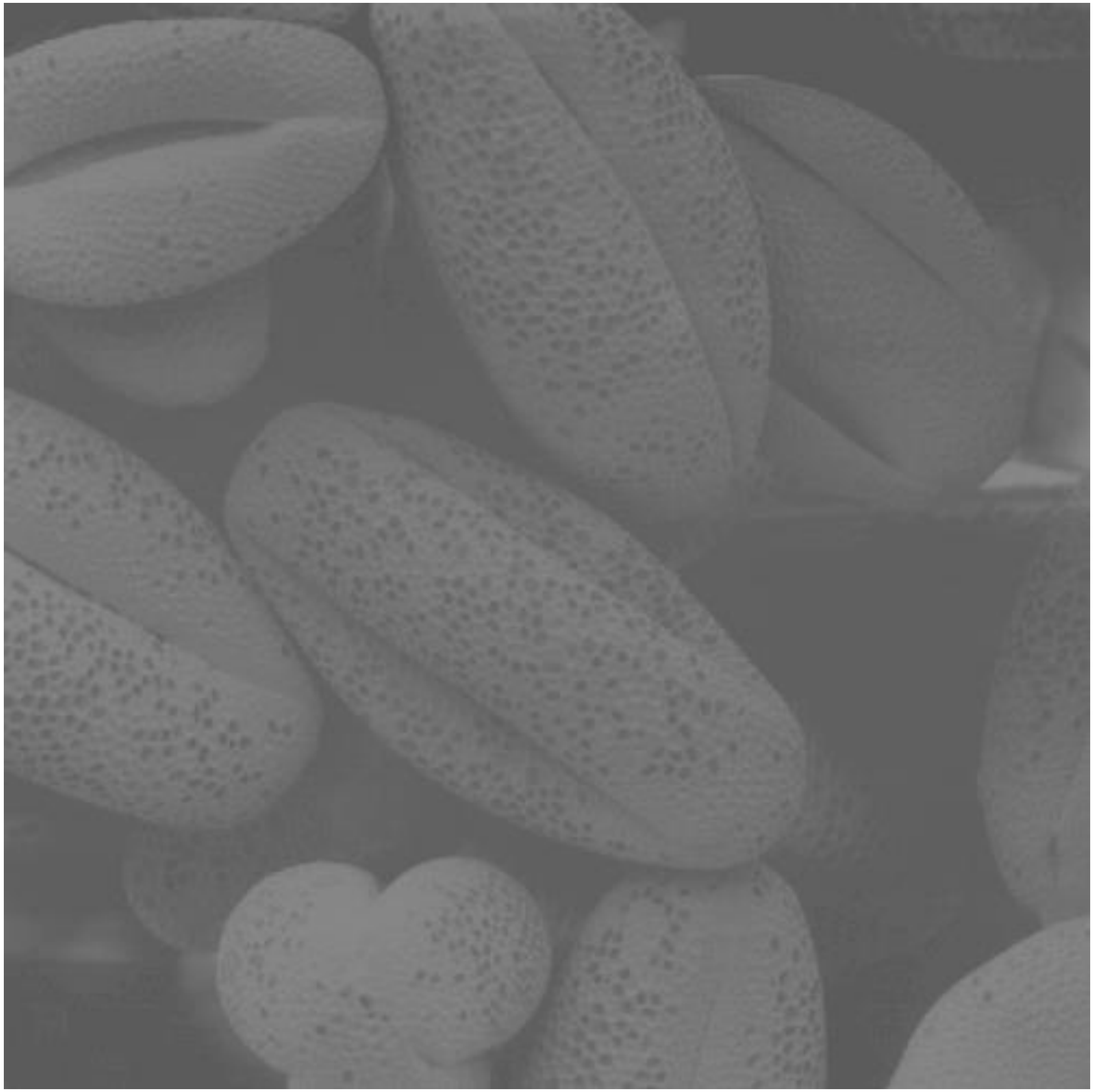
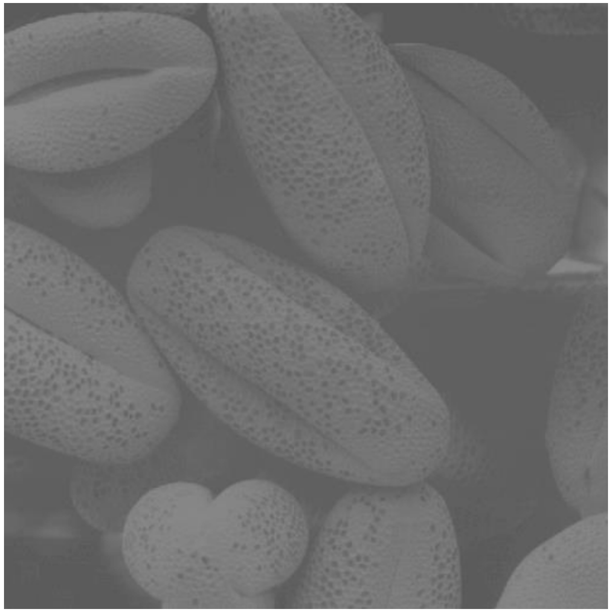
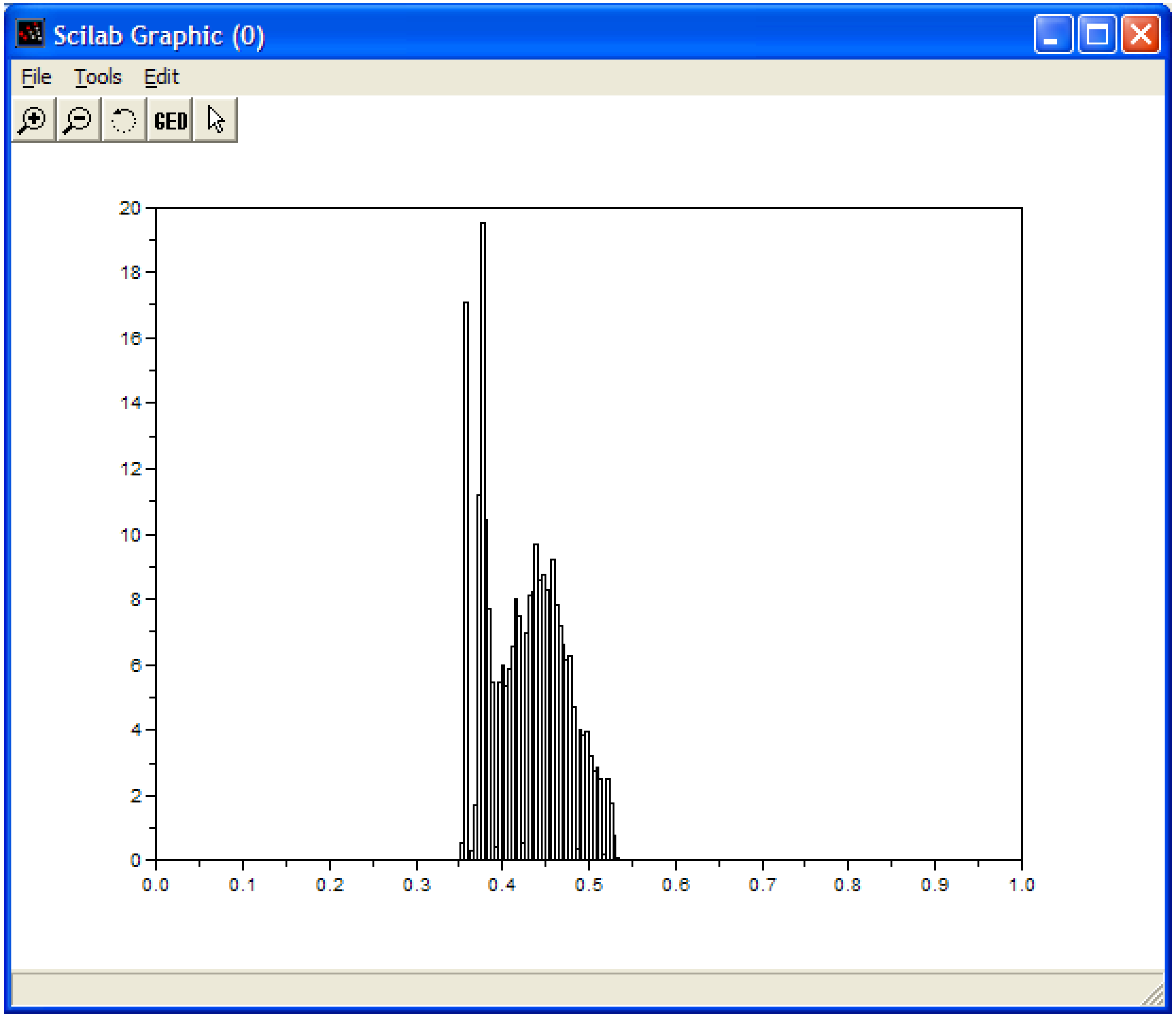


Histogram Examples (cont…)



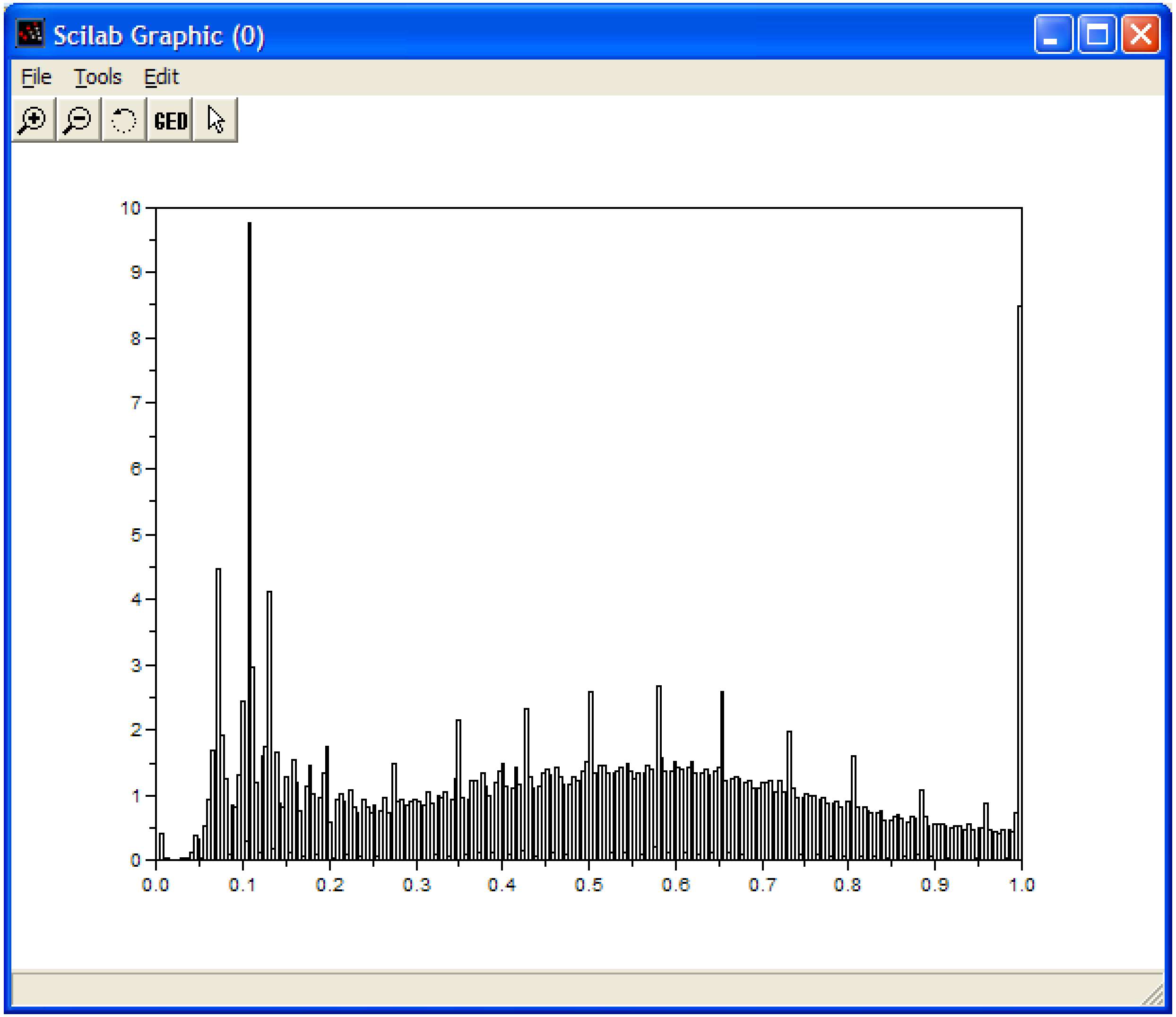
Histogram Examples (cont…)





Histogram Examples (cont…)

Histogram Examples (cont…)

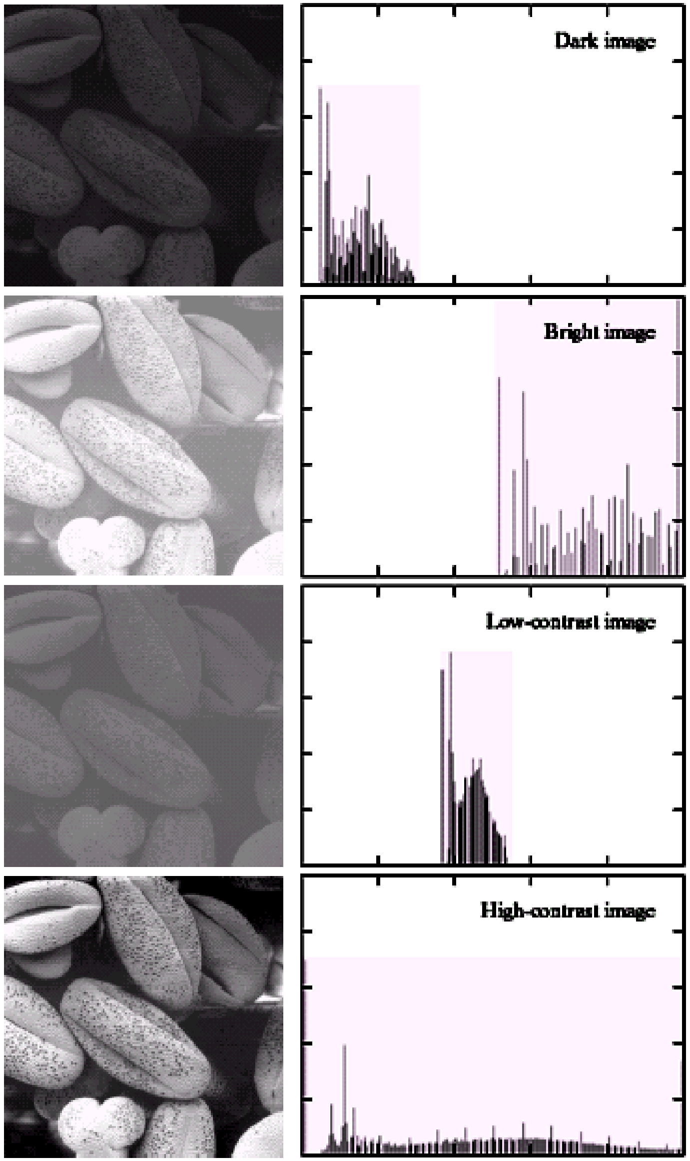


Histogram Examples (cont…)

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

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

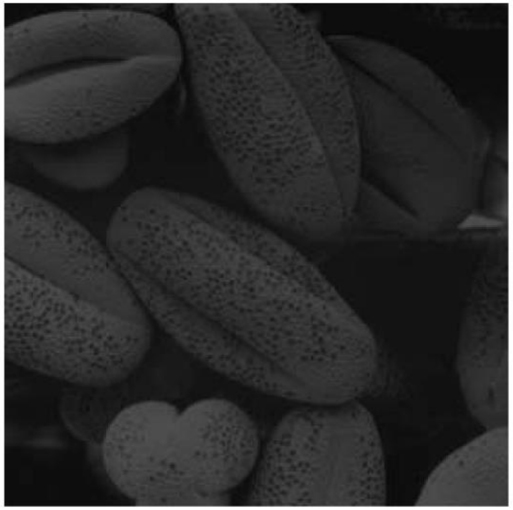
Spreading out the frequencies in an image (or equalising the image) is a simple way to improve dark or washed out images

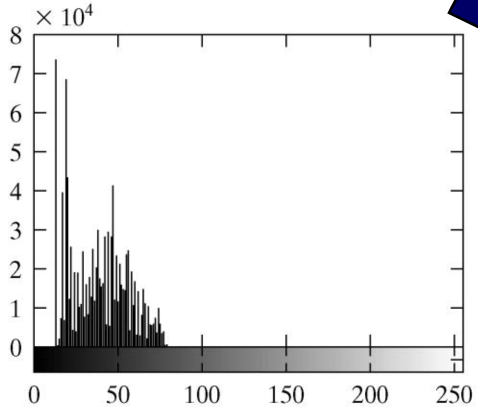
The formula for histogram equalisation is given where

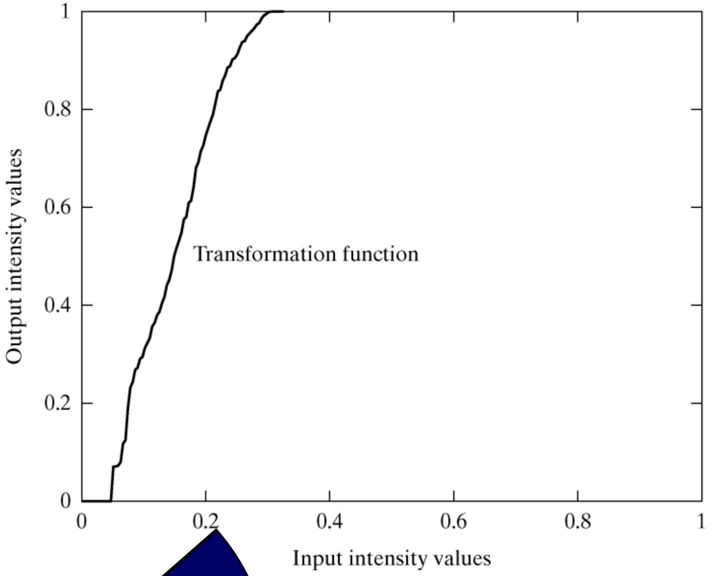
- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)
- n_j: the frequency of intensity j
- n: the sum of all frequencies

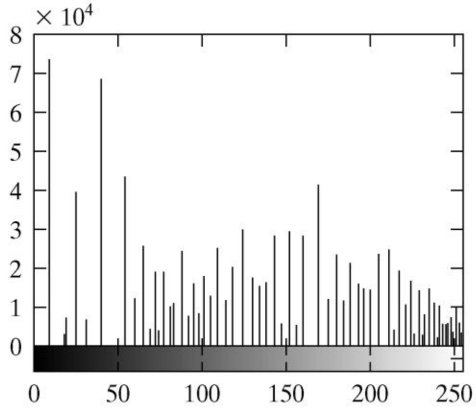
$$\begin{aligned} s_k &= T(r_k) \\ &= \sum_{j=1}^{k} p_r(r_j) \\ &= \sum_{j=1}^{k} \frac{n_j}{n} \end{aligned}$$

Equalisation Transformation Function

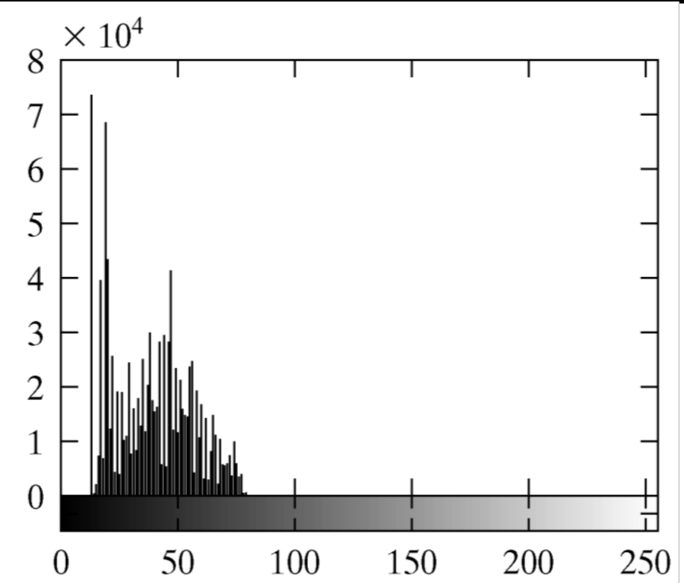


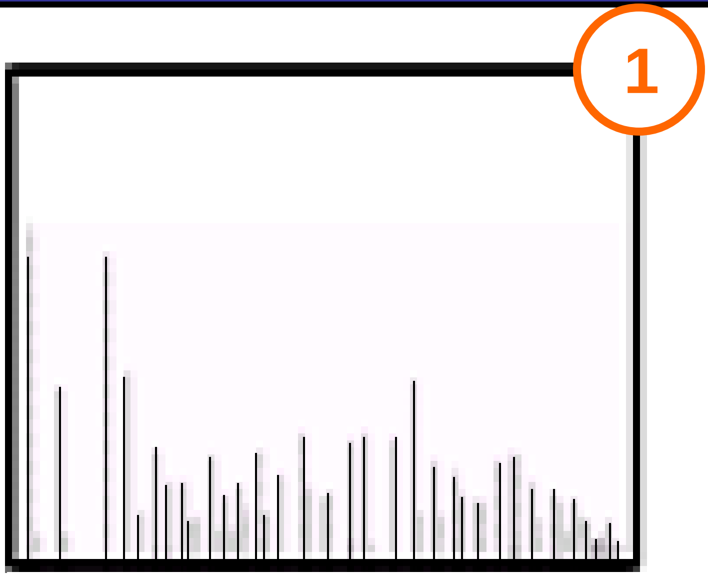


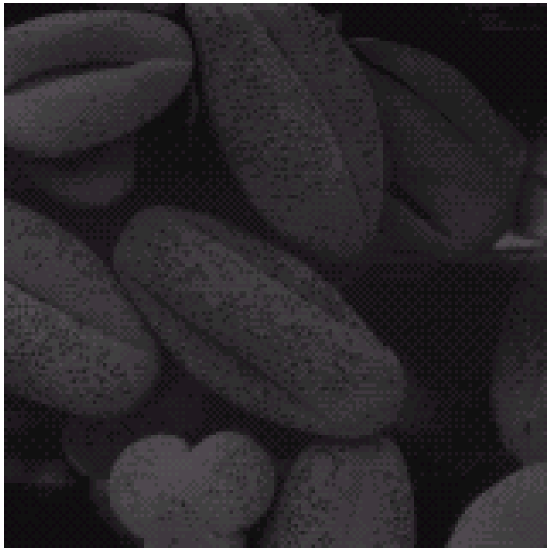




Equalisation Examples

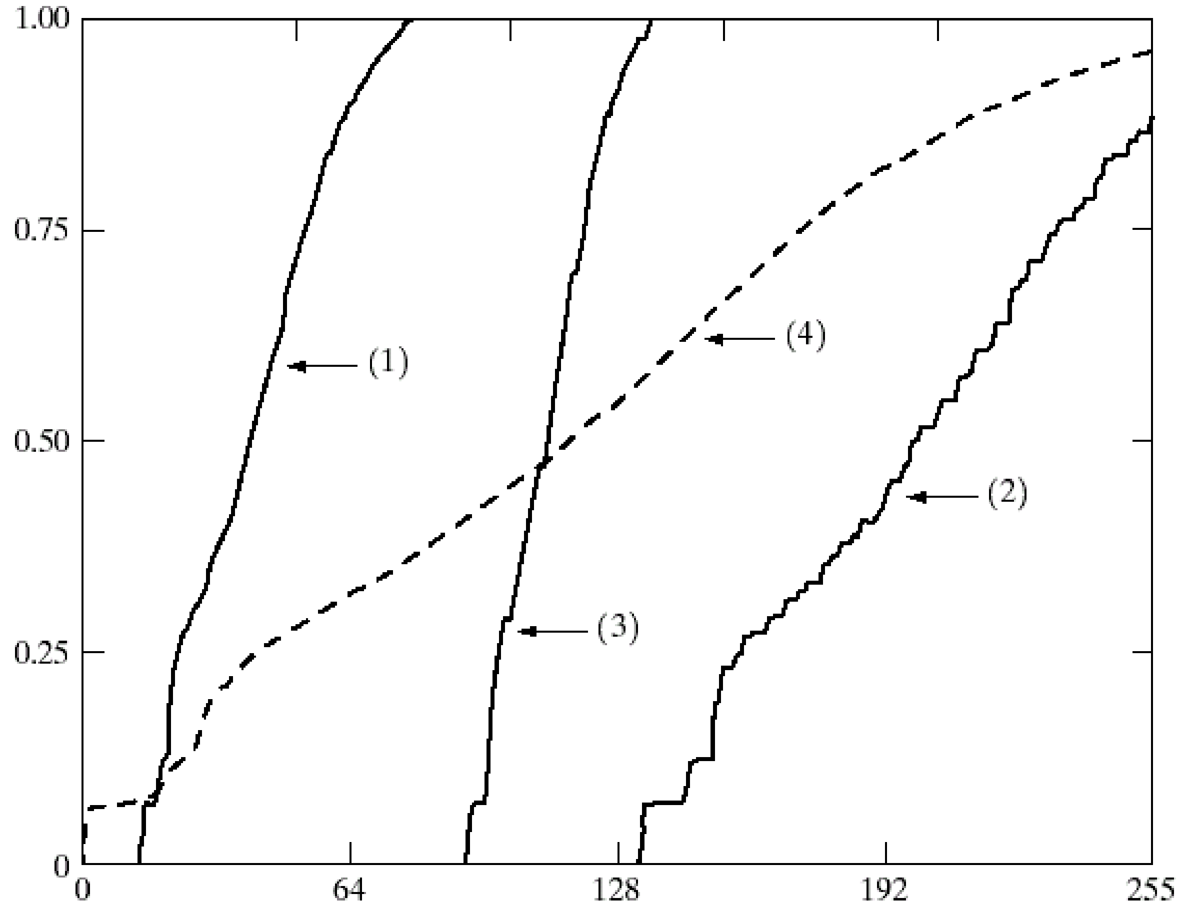




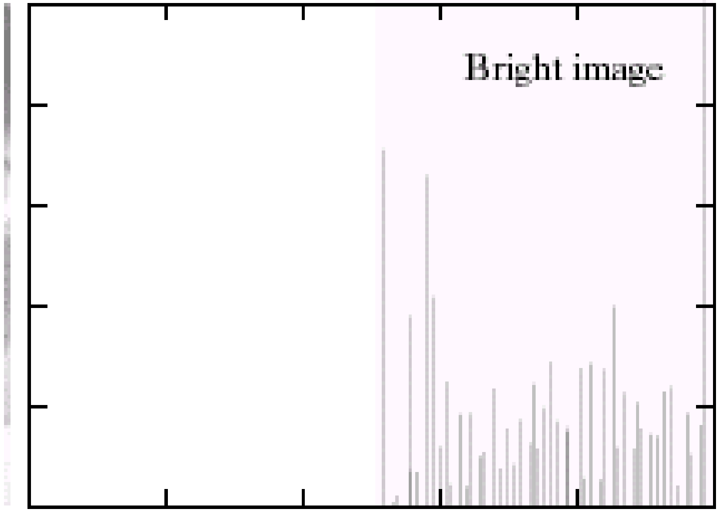


Equalisation Transformation Functions

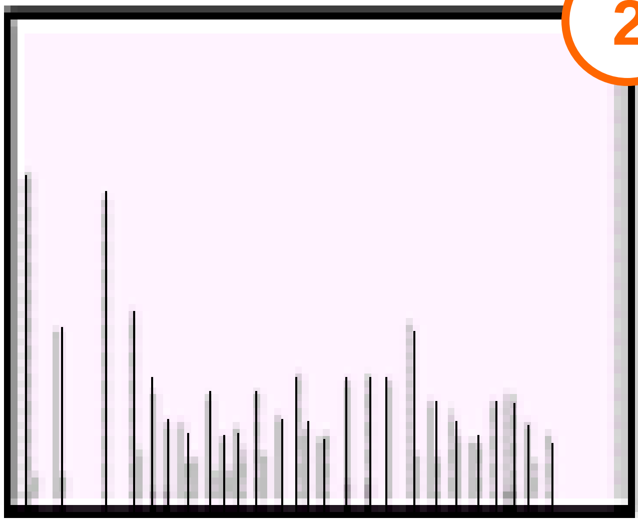
The functions used to equalise the images in the previous example



Equalisation Examples



2



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

Equalisation Transformation Functions

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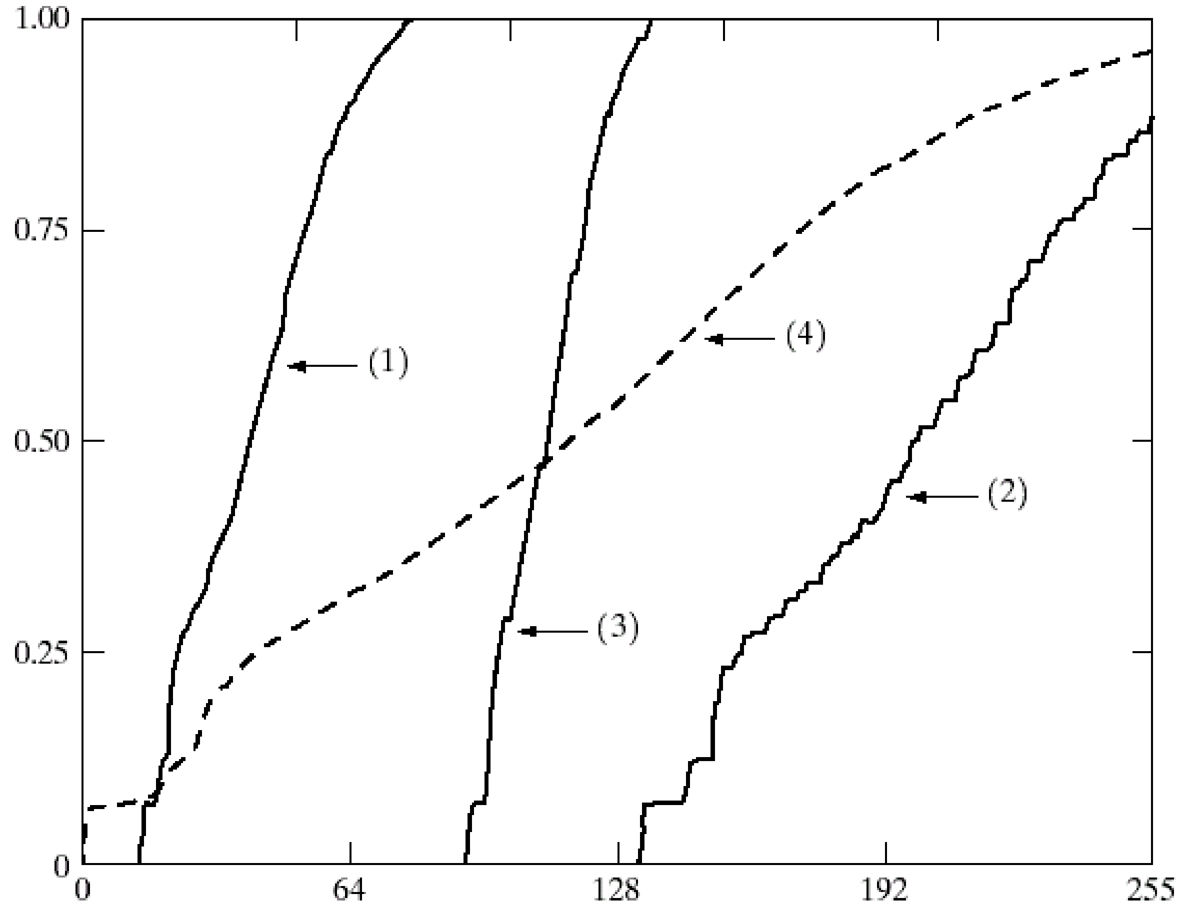
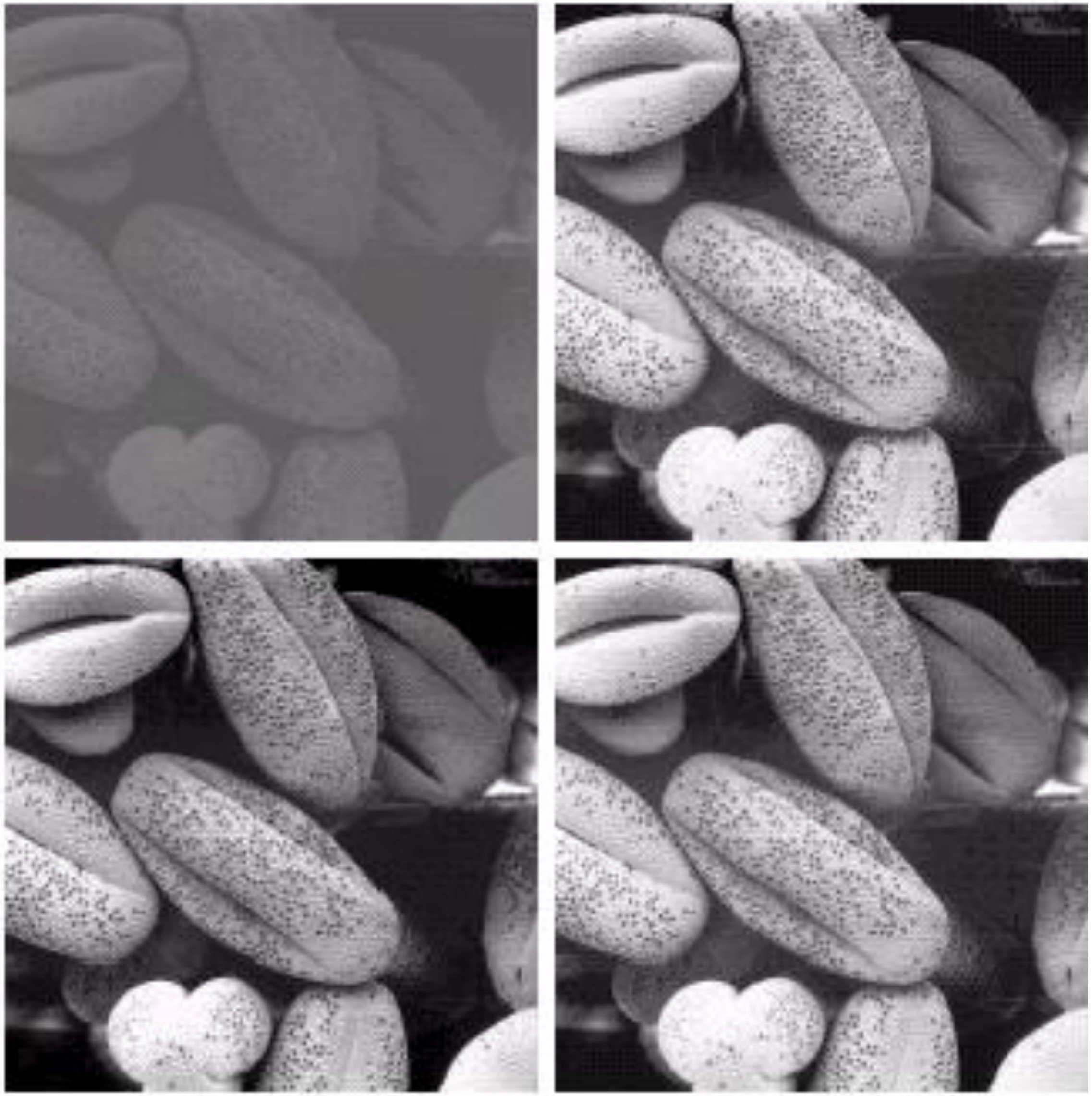
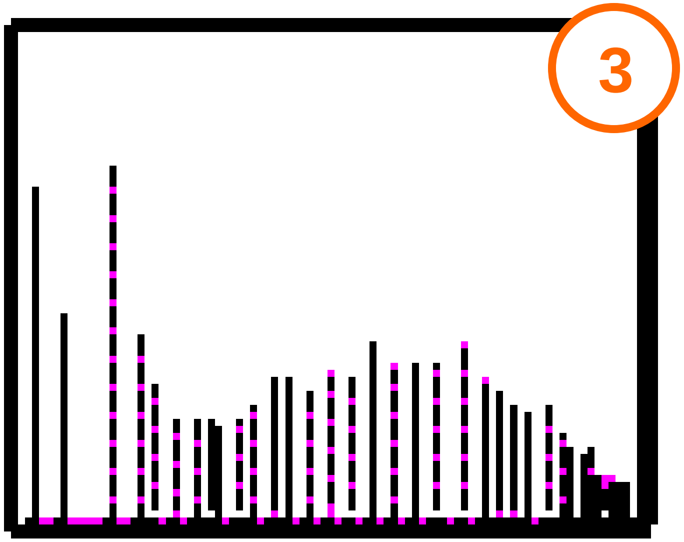
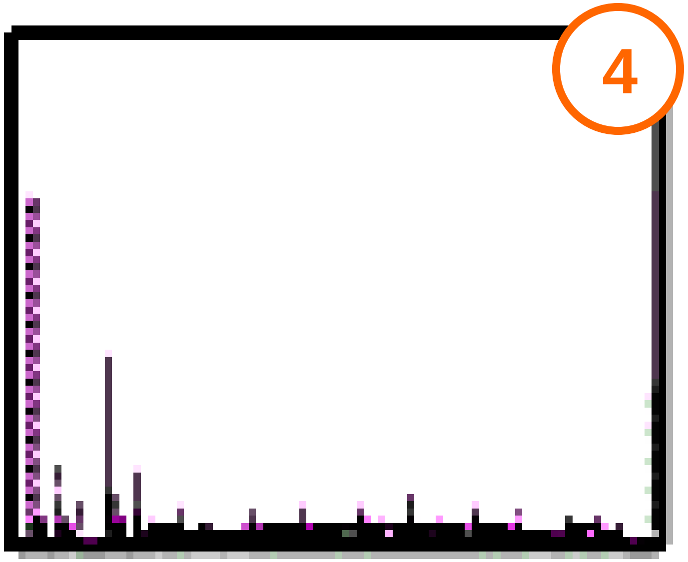


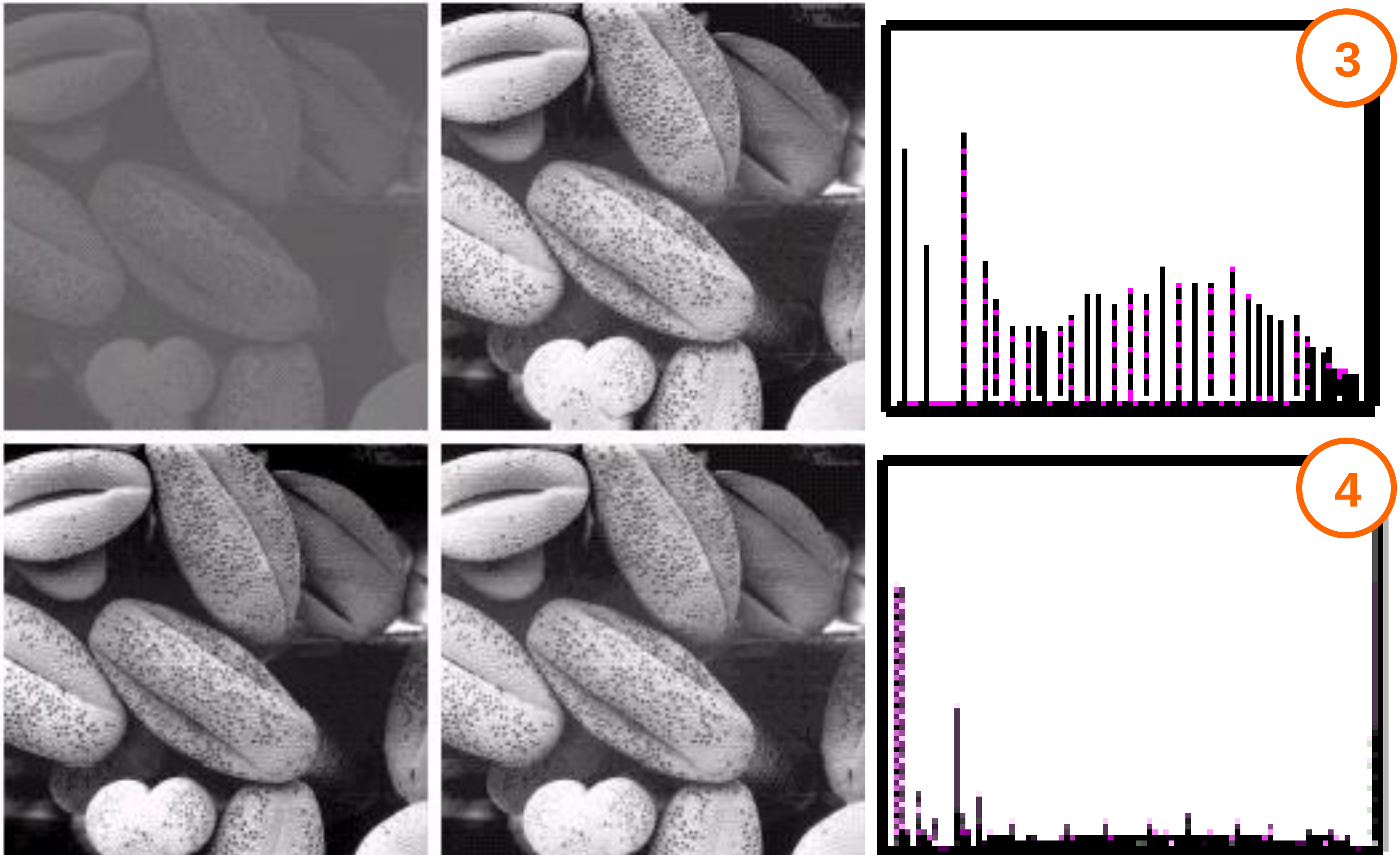
Equalisation Examples (cont…)





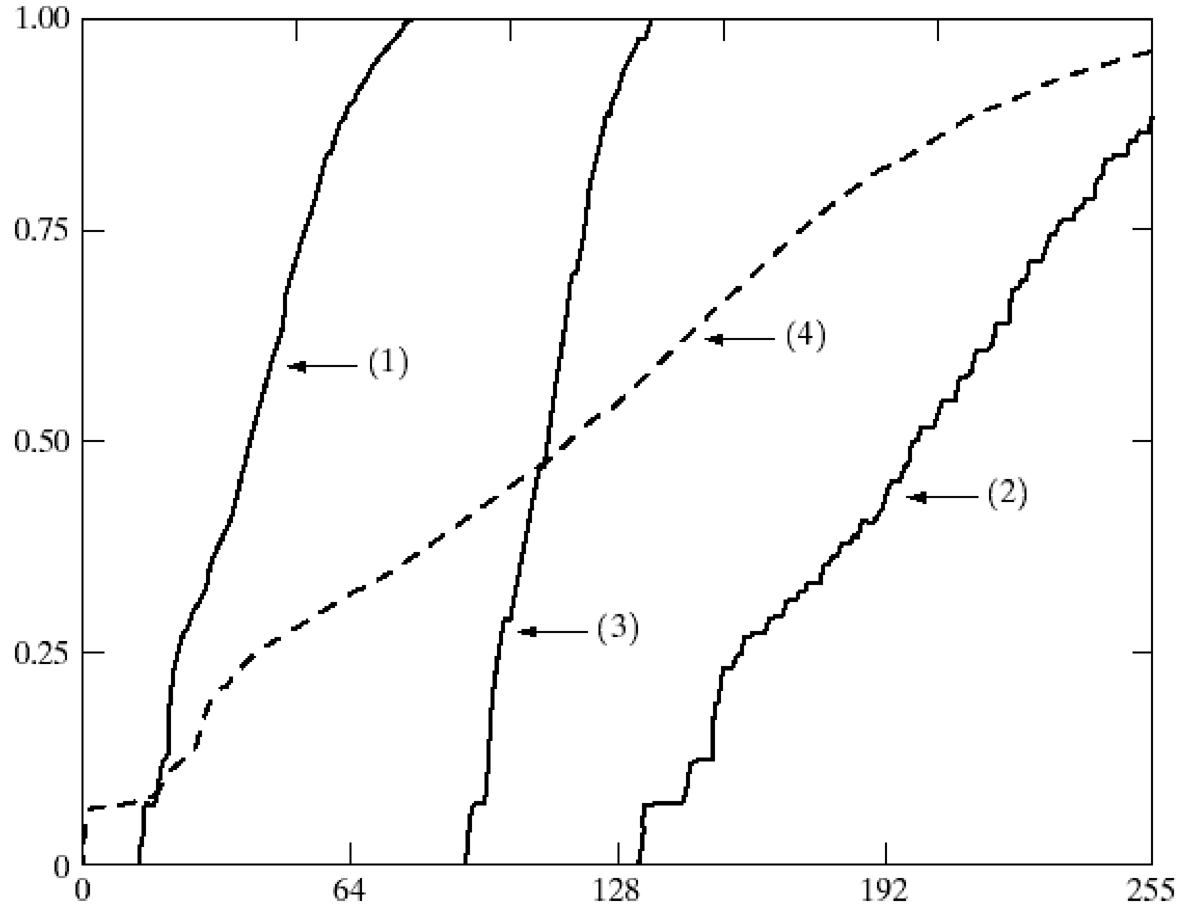


Equalisation Examples (cont…)

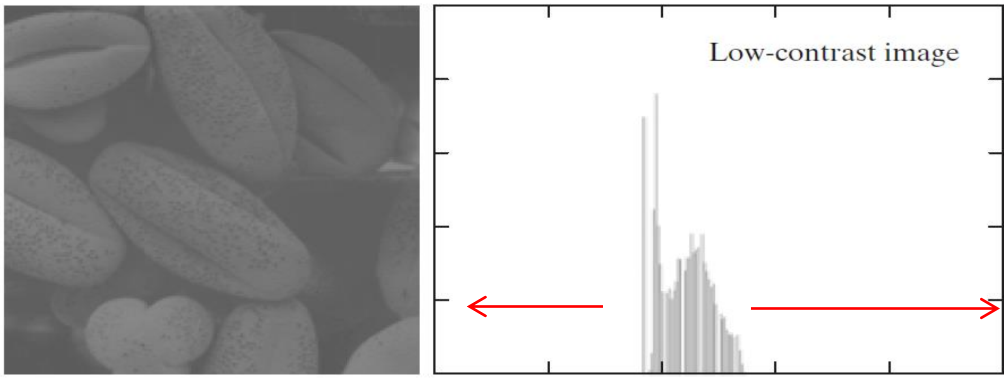


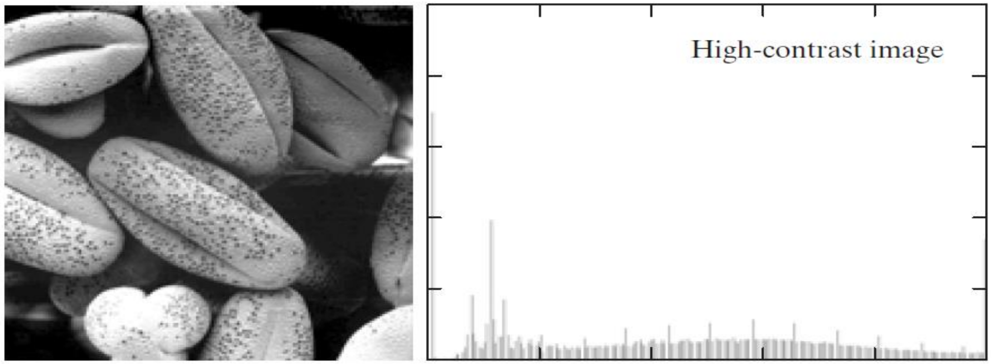
Equalisation Transformation Functions

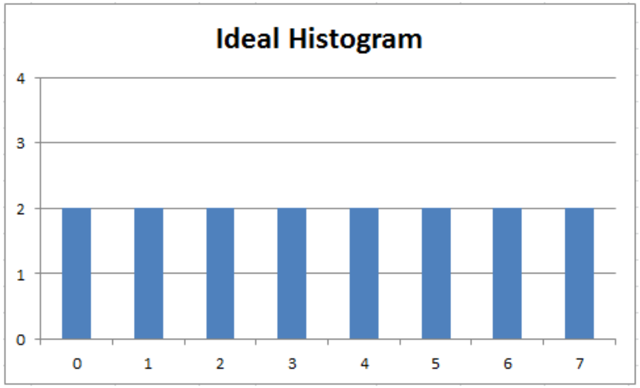
The functions used to equalise the images in the previous examples



Histogram equalization







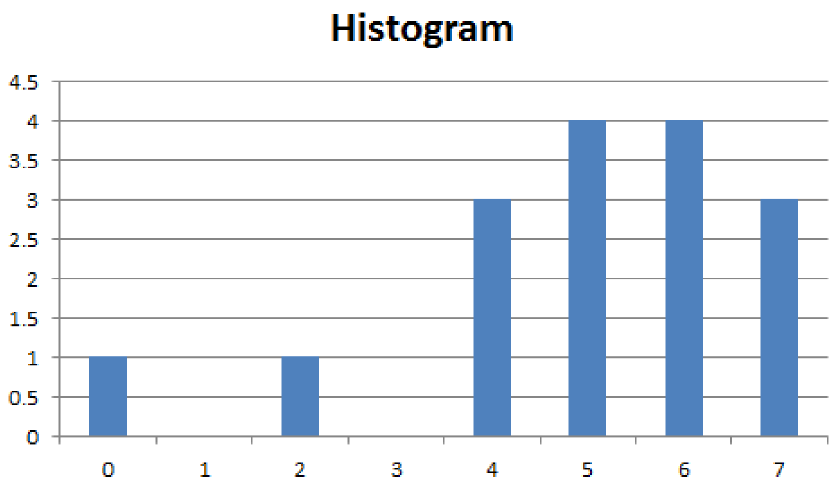
- Cumulative Distribution Function: $cdf(r)$ the total number of pixels with intensity up to *r*

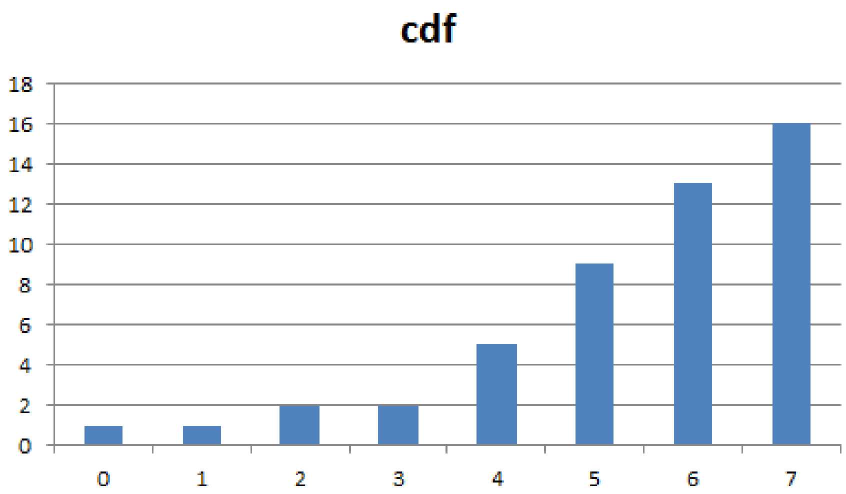
$$cdf(r) = \sum_{i=0}^{r} h(i)$$

- Histogram $h(r)$ the number of pixels with intensity *r*

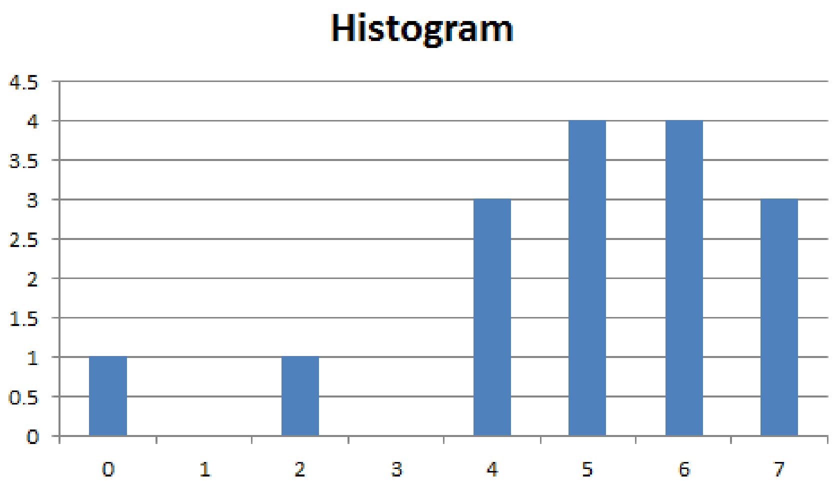
Intensity	0	1	2	3	4	5	6	7
Histogram	1	0	1	0	3	4	4	3
N.Histogram	0.0625	0	0.0625	0	0.1875	0.25	0.1875	0. 25
cdf	1	1	2	2	5	9	13	16

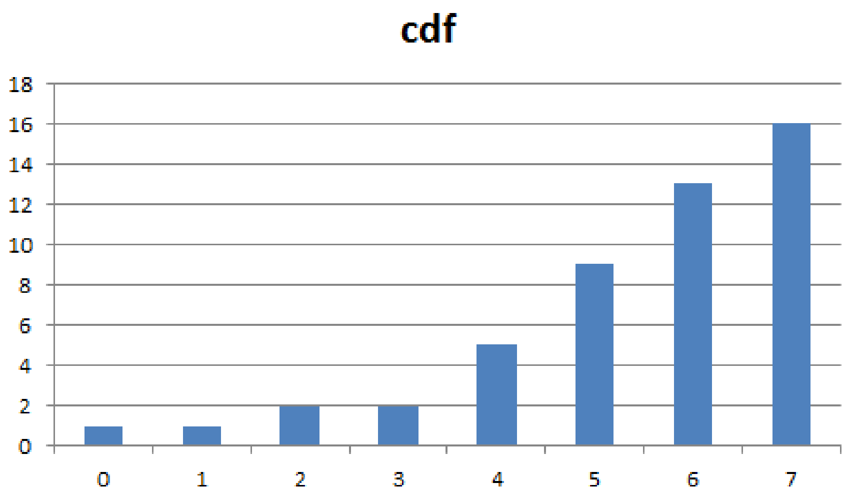
Histogram and cumulative distribution function





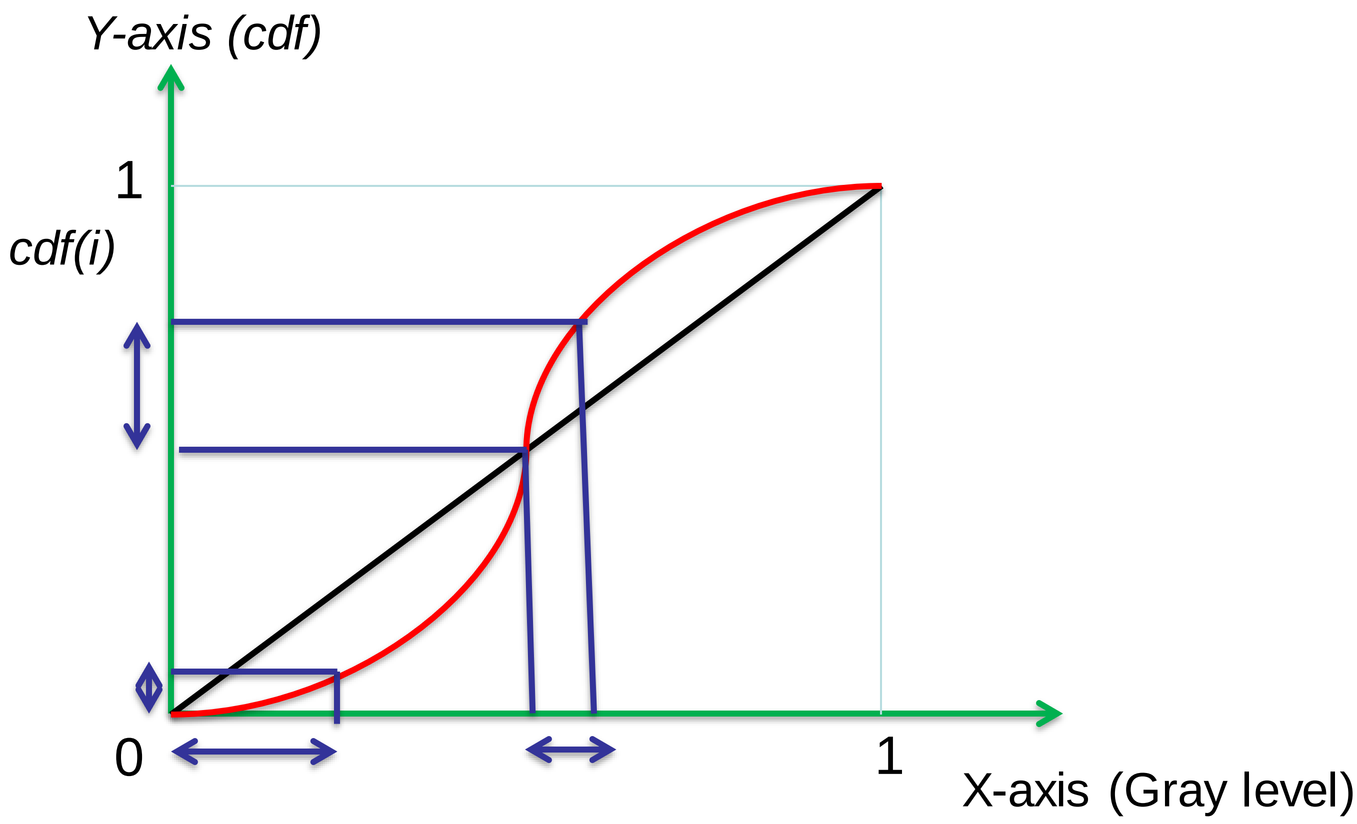
Histogram and CDF are identical





Ideal histogram ⇔ Ideal CDF

Histogram Equalization Technique



Histogram Equalization Technique

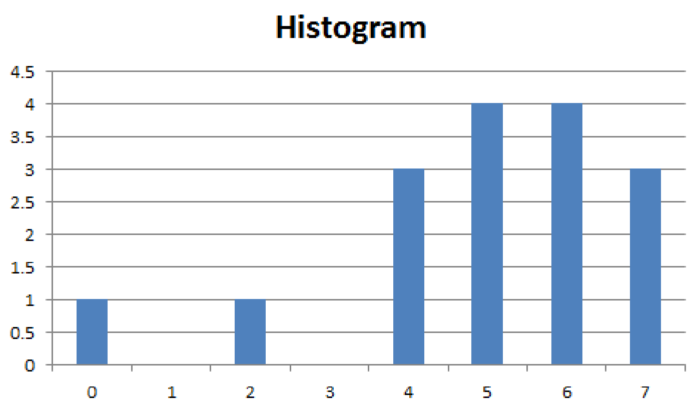
2	**5**	**7**	**6**
4	**5**	**4**	**7**
6	**5**	**6**	**4**
0	**7**	**5**	**6**

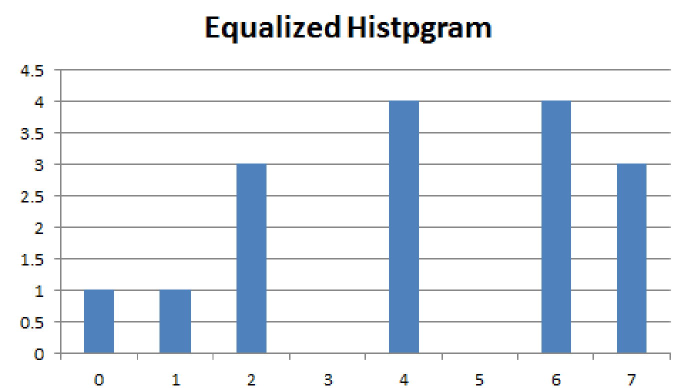
Intensity	0	1	2	3	4	5	6	7
Histogram	1	0	1	0	3	4	4	3
N.Histogram	0.0625	0	0.0625	0	0.1875	0.25	0.1875	0. 25
cdf	1	1	2	2	5	9	13	16
N.cdf	0.0625	0.0625	0.125	0.125	0.3125	0.5625	0.8125	1
N.cdf*L	0.4375	0.4375	0.875	0.875	2.1875	3.9375	5.6875	7
New Intensity	0	0	1	1	2	4	6	7

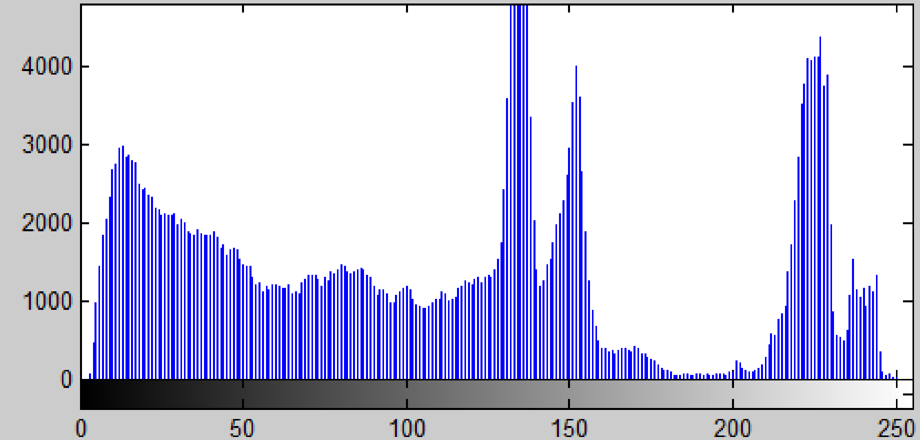
Histogram Equalization Technique

2	5	7	6
4	5	4	7
6	5	6	4
0	7	5	6

1	4	7	6
2	4	2	7
6	4	6	2
0	7	4	6



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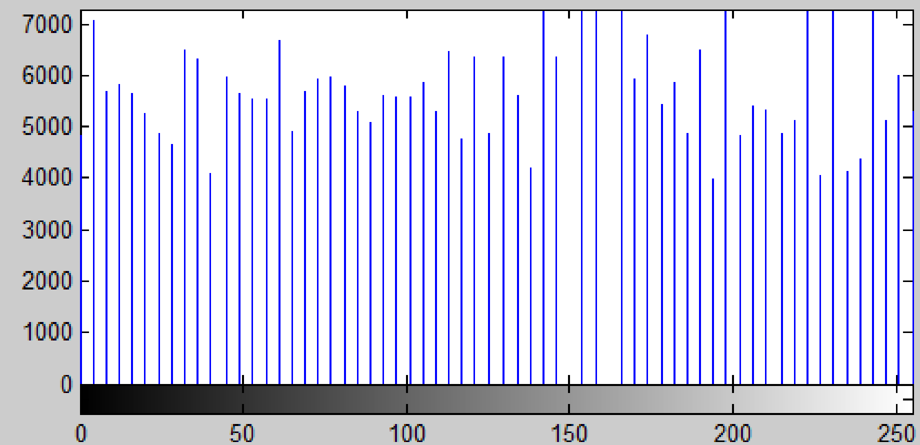
3000
2000
1000
0
0
50
100
150
200
250


7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250

Thank you for your attention !