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 technologies

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

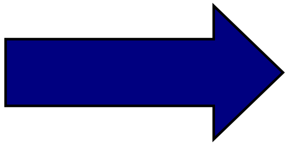


Image Enhancement Examples (cont…)

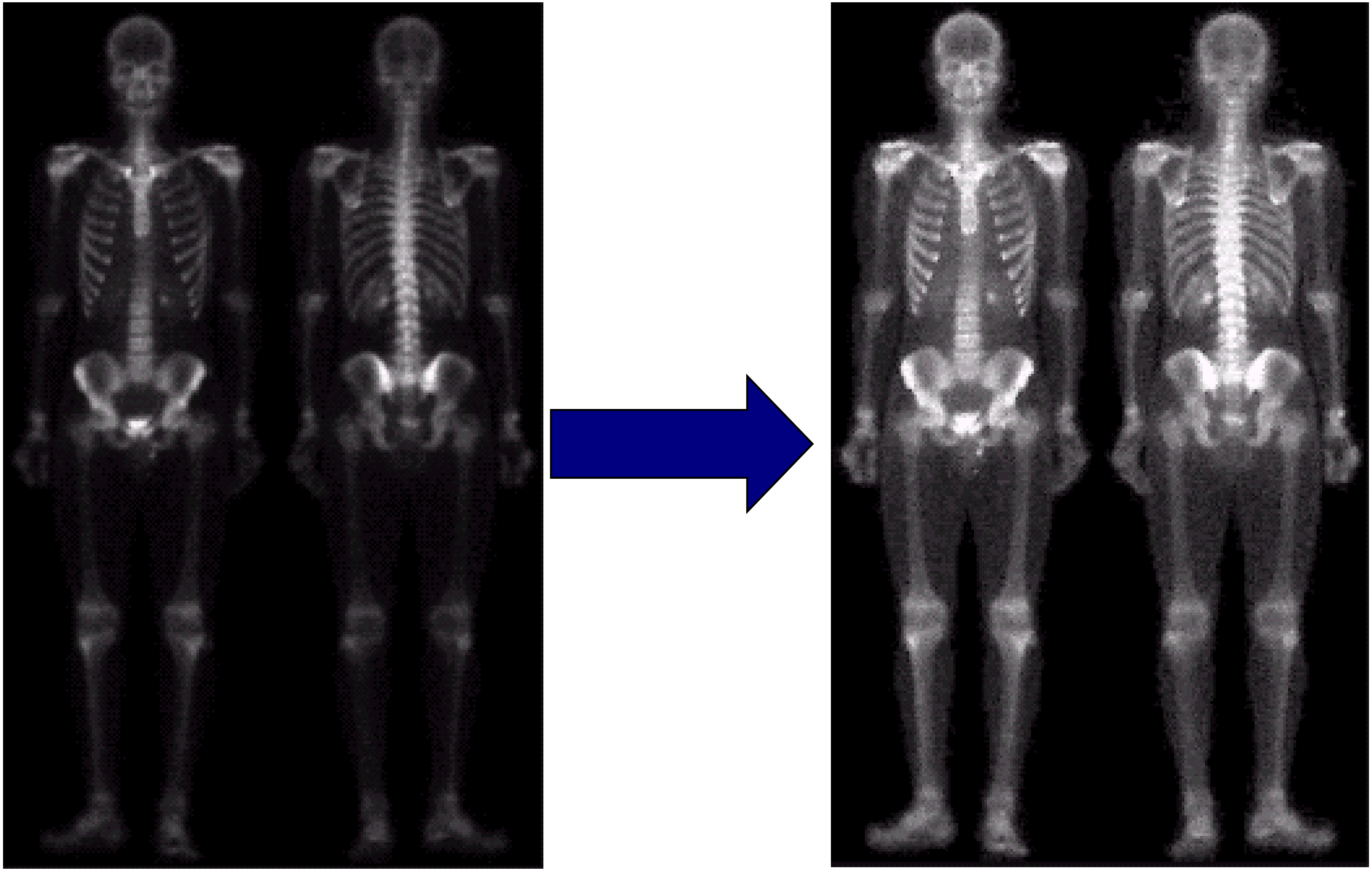


Image Enhancement Examples (cont…)

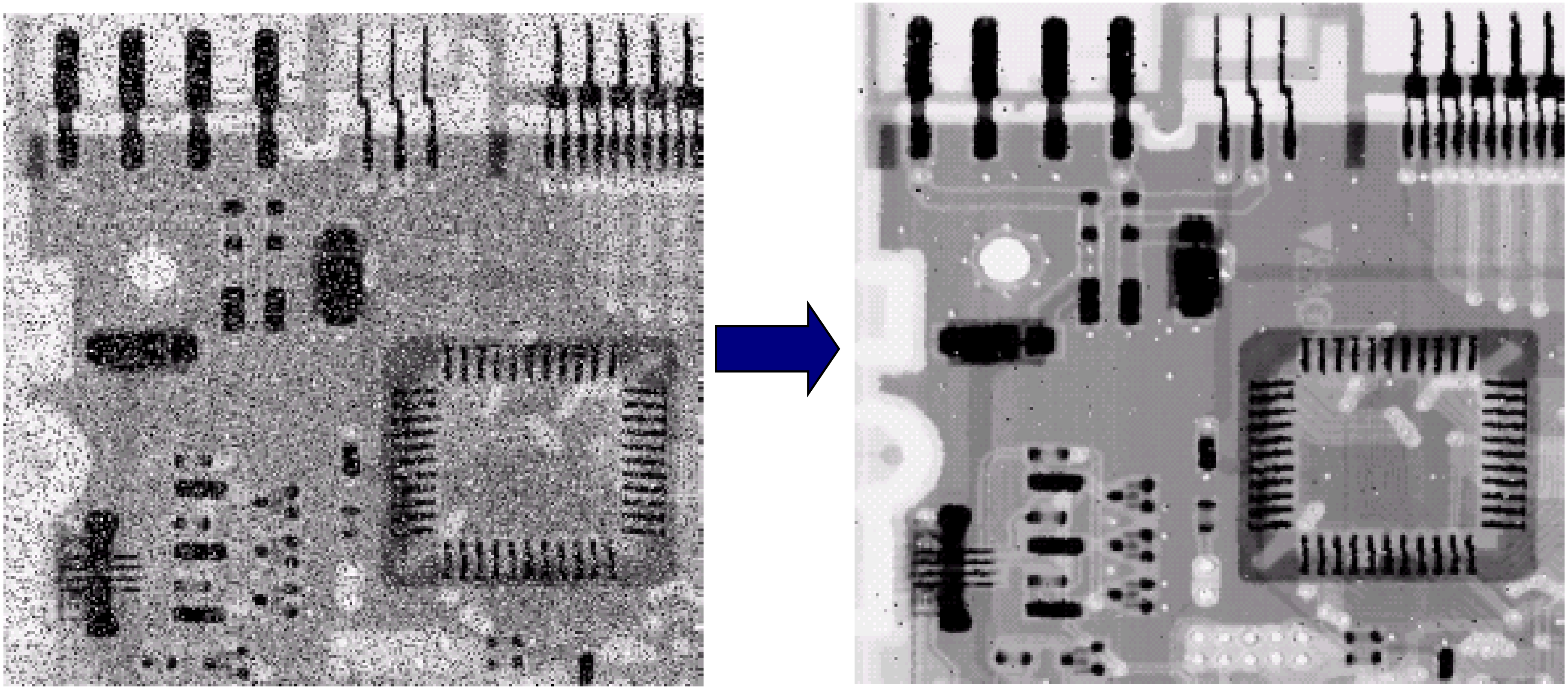


Image Enhancement Examples (cont…)

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.

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.

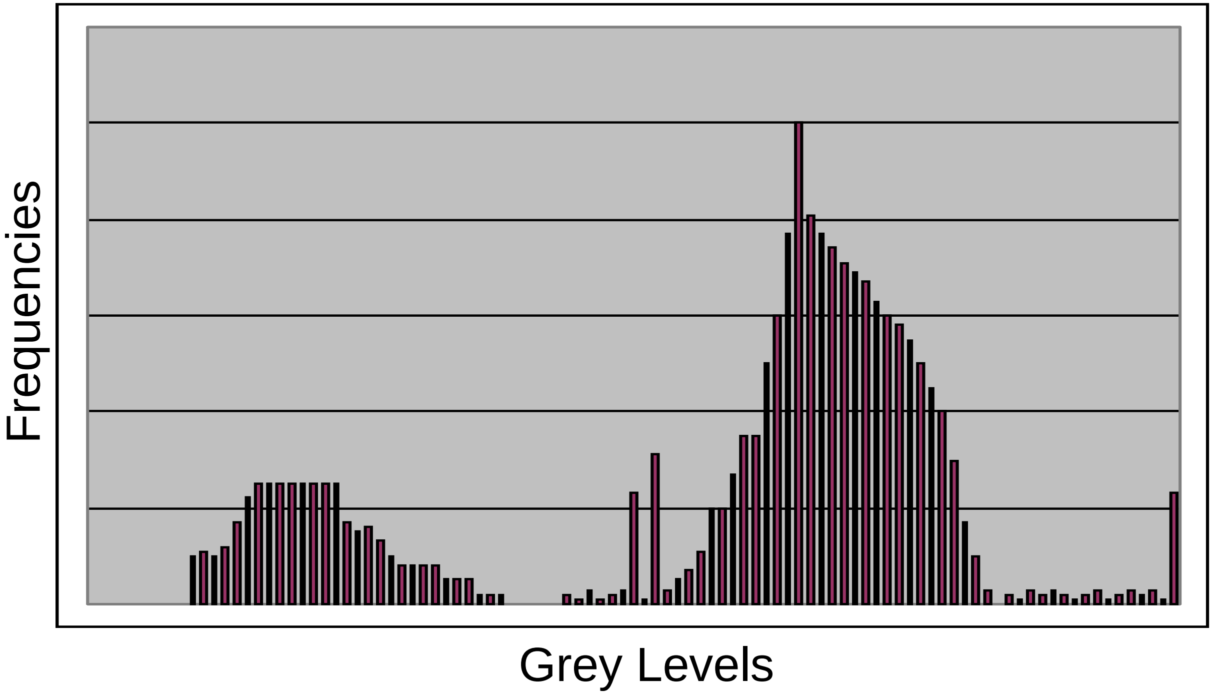


Image Histograms

Histograms plots how many times (frequency) each intensity value in image occurs

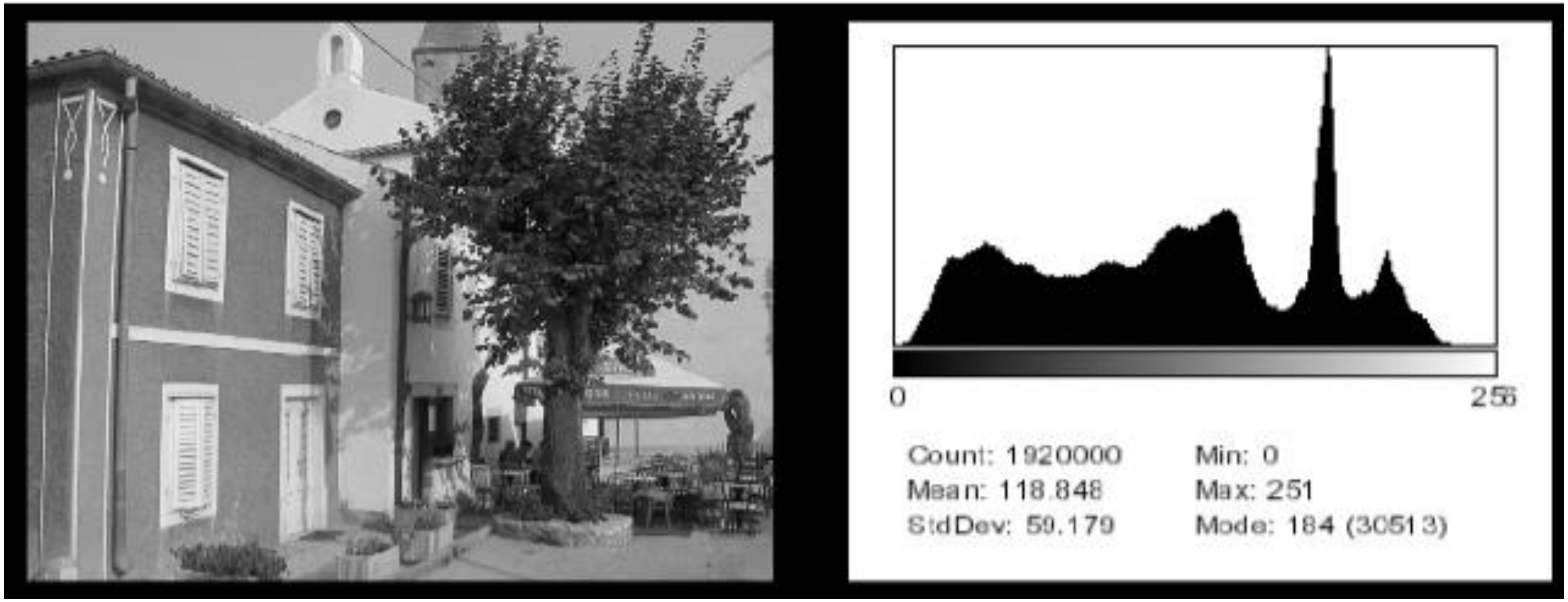
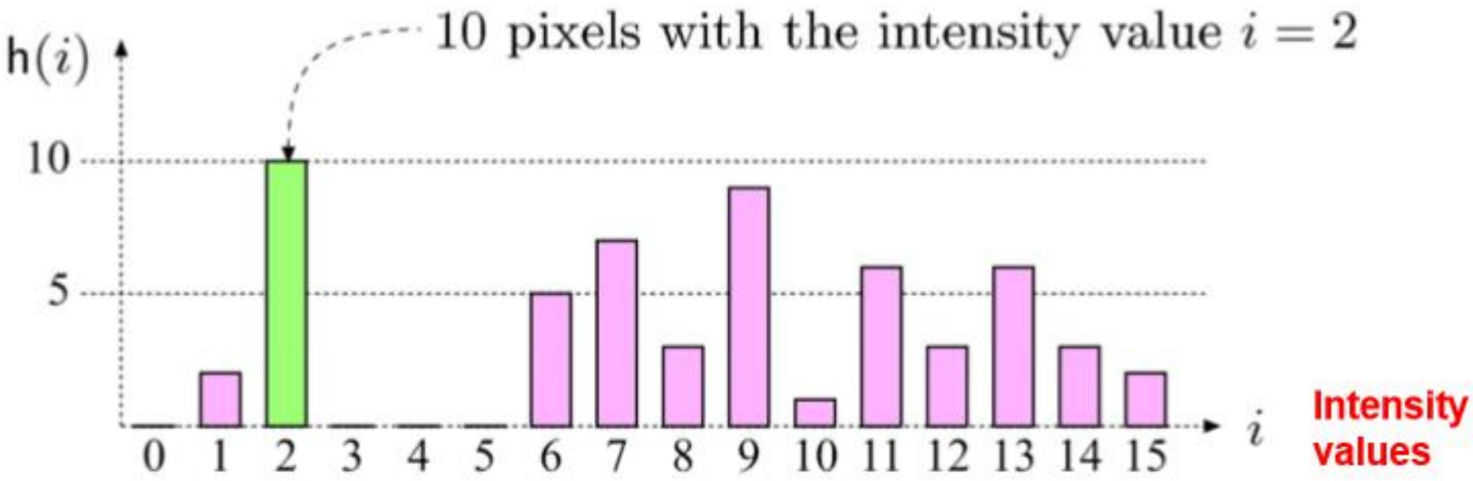


Image Histograms

- Many cameras display real time histogram of a scene.
- Also easier to detect types of processing previously applied to image

Image Histograms



h(i)	0	2	10	0	0	0	5	7	3	9	1	6	3	6	3	2
i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

- Histograms: only statistical information
- No indication of pixels locations

Image Histograms

- Different images can have same histogram
- 3 images below have same histogram

- Half of pixels are gray, half are white
- Same histogram = same statisics
- Distribution of intensities could be different

- Can we reconstruct image from histogram? **NO**

Image Histograms

The histogram of a digital image with gray levels in the range [0, L-1] is a discrete function

$$h(r_k) = n_k$$

r_k: the kth gray level

n_k: the number of pixels in the image having gray level r_k

Normalized histogram

Dividing each of its values by the total number of pixels in the image (n).

$$p(r_k) = n_k / n$$

For k = 0,1,……., L-1.

$p(r_k)$: Gives an estimate of the probability of occurrence of gray level r_k.

The sum of all components of a normalized histogram is equal to 1.

Image Contrast

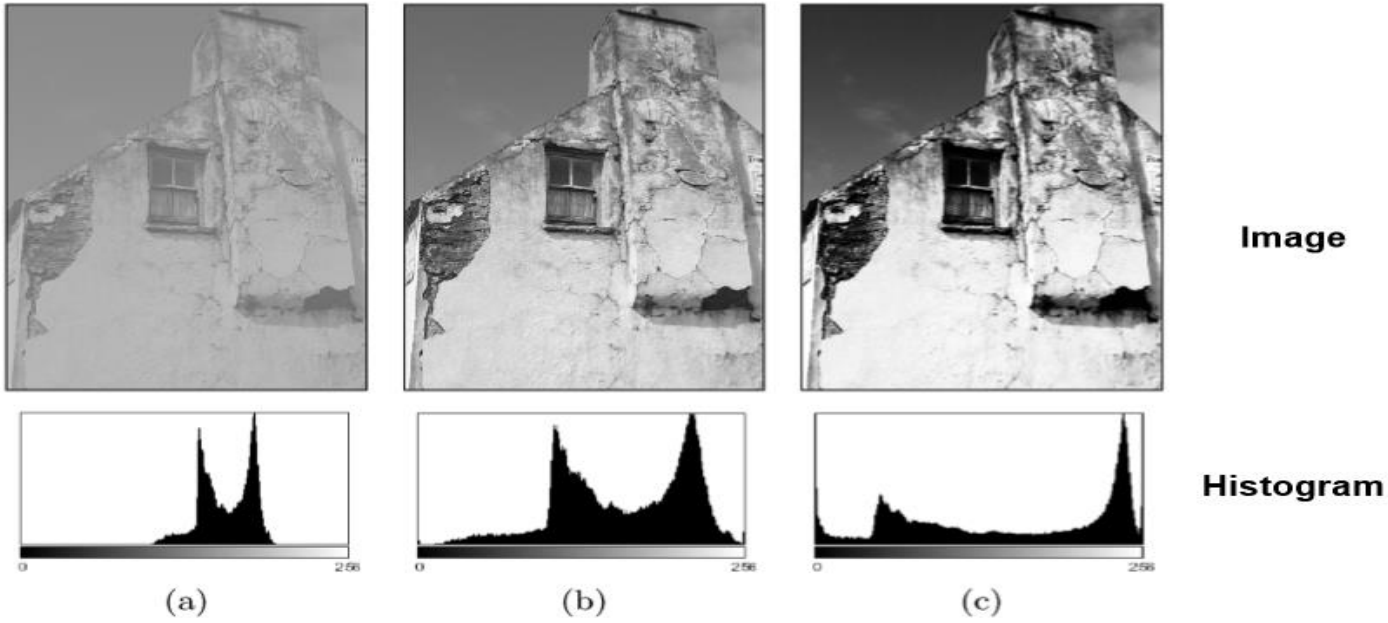
The contrast of a grayscale image indicates how easily objects in the image can be distinguished

- **High contrast image:** many distinct intensity values.
- **Low contrast:** image uses few intensity values.

Histograms and Contrast

Good Contrast?

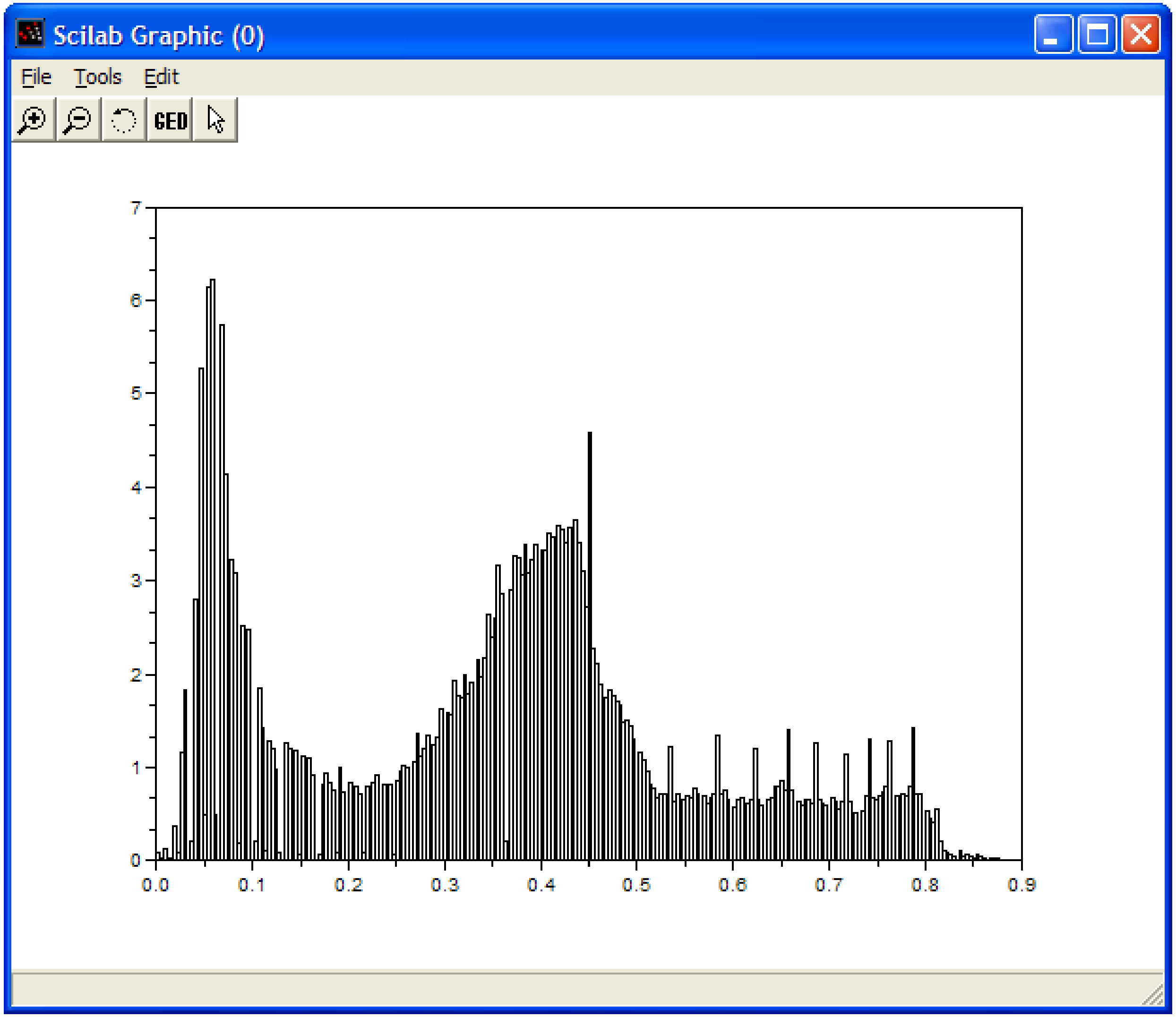
Widely spread intensity values + large difference between min and max intensity values



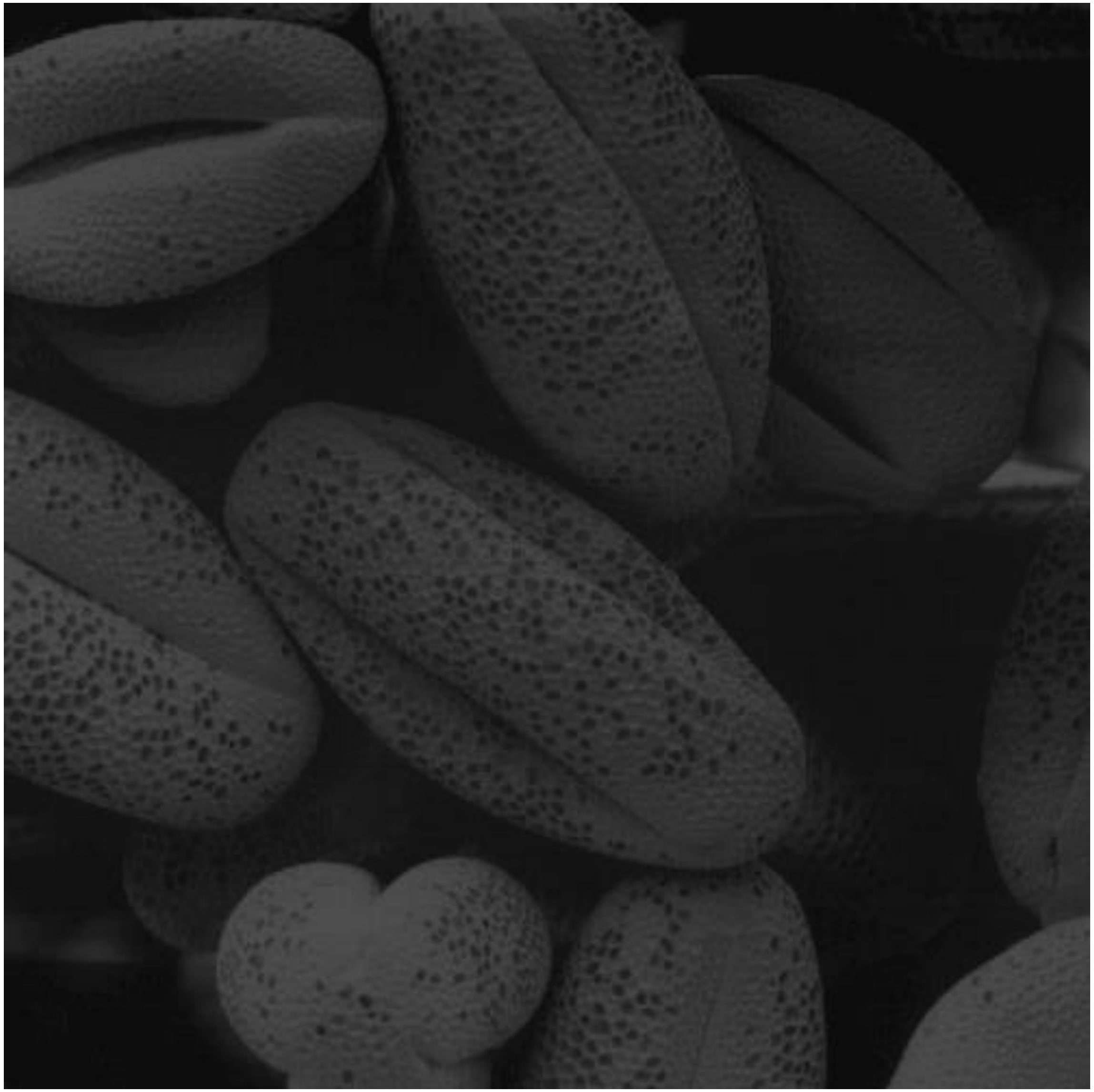
Low contrast Normal contrast High contrast

Histogram Examples

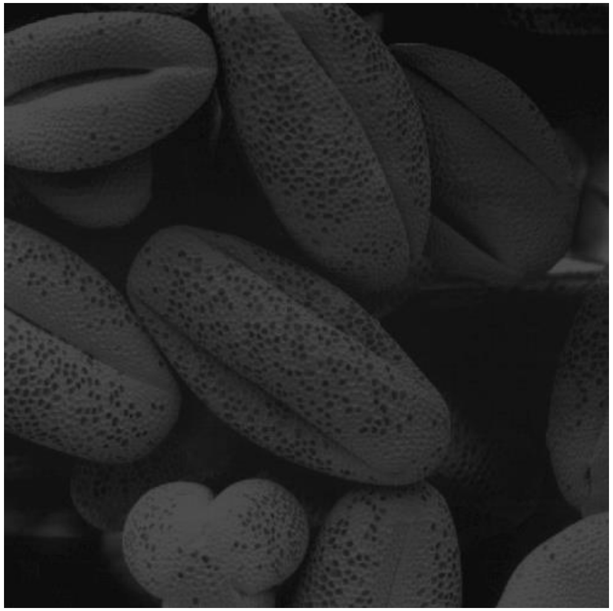
Histogram Examples (cont…)

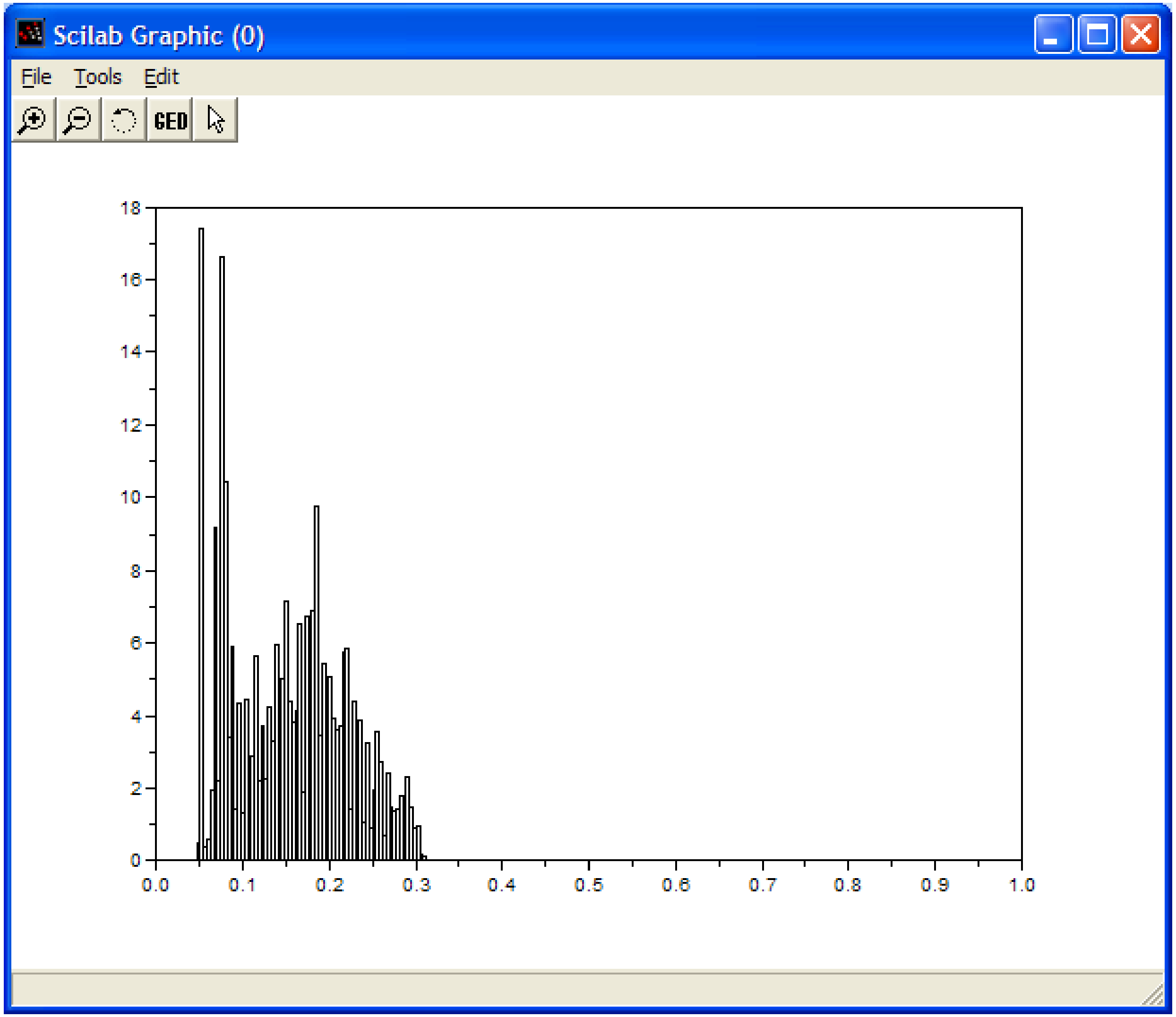


Histogram Examples (cont…)



Histogram Examples (cont…)





Histogram Examples (cont…)

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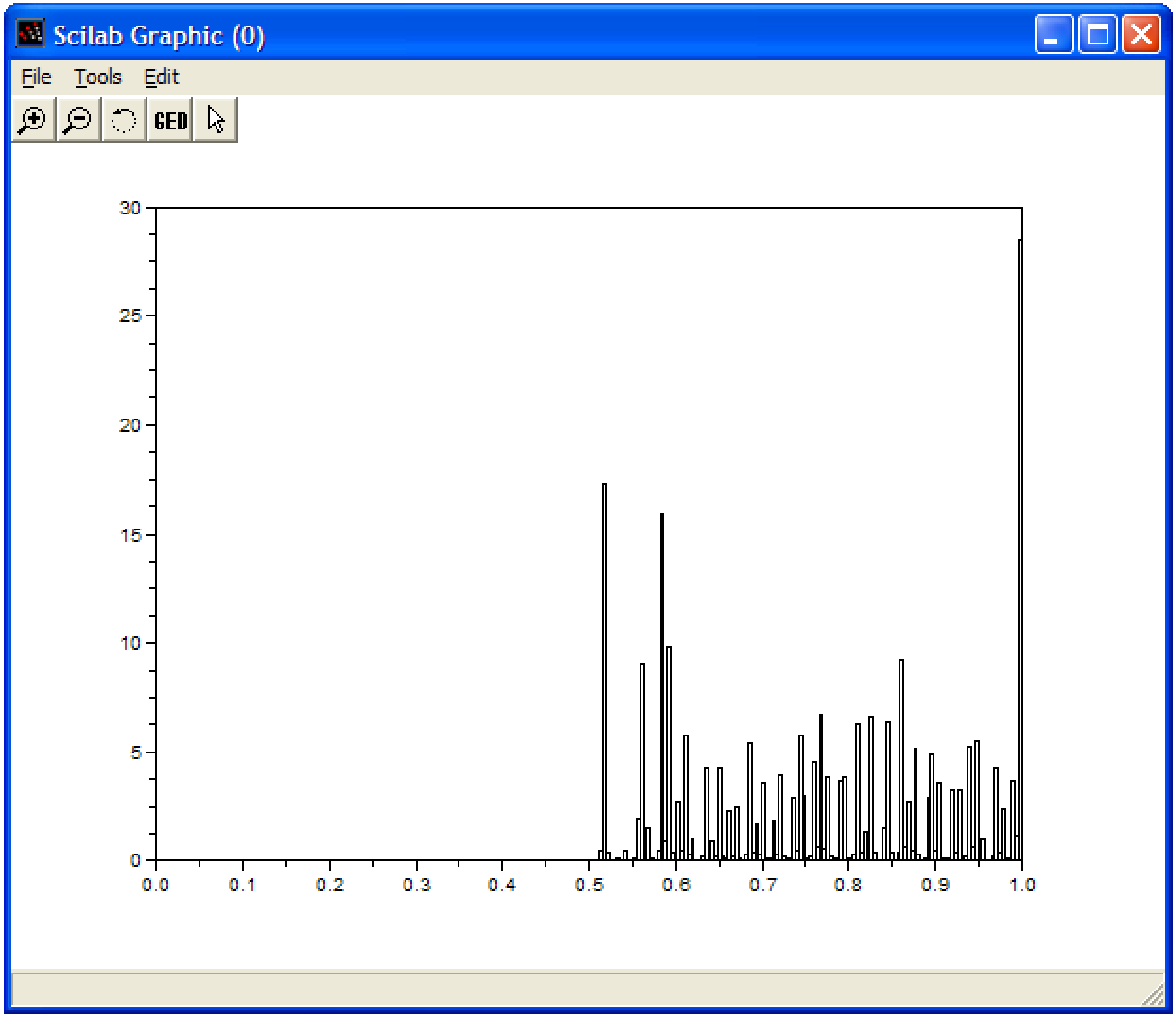
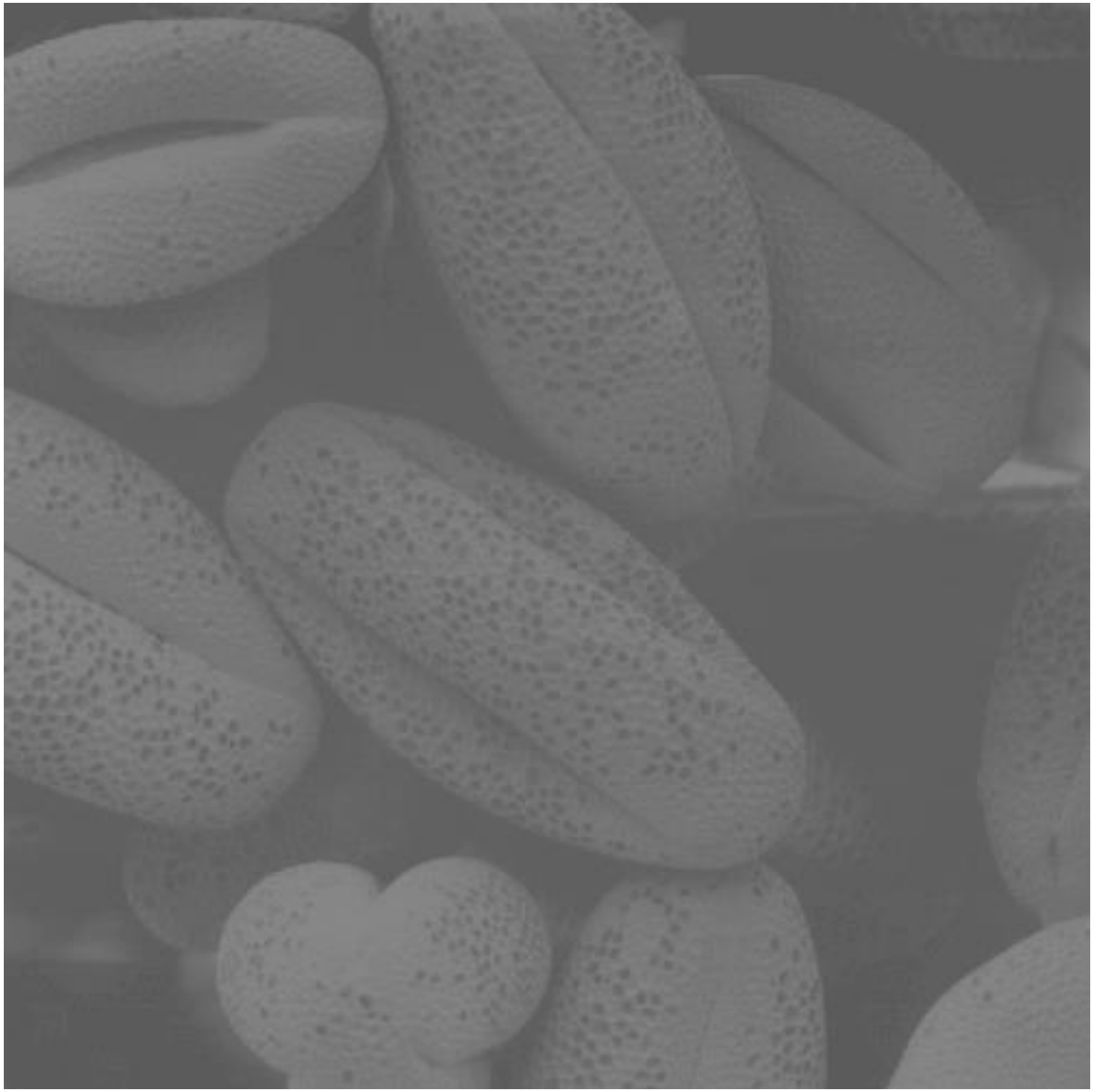
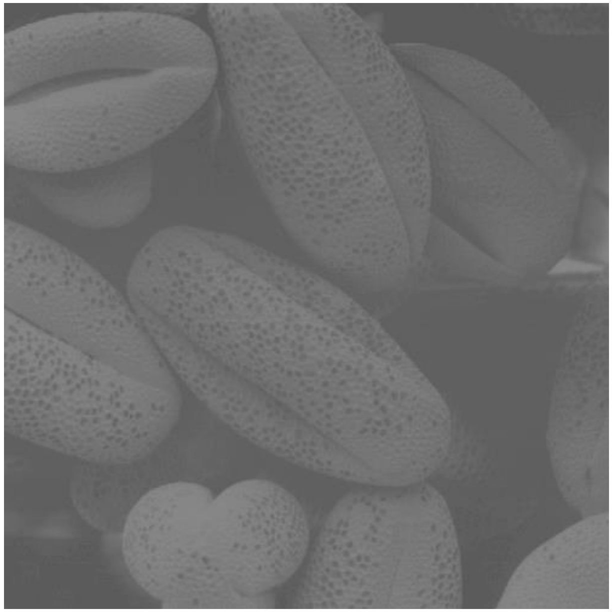
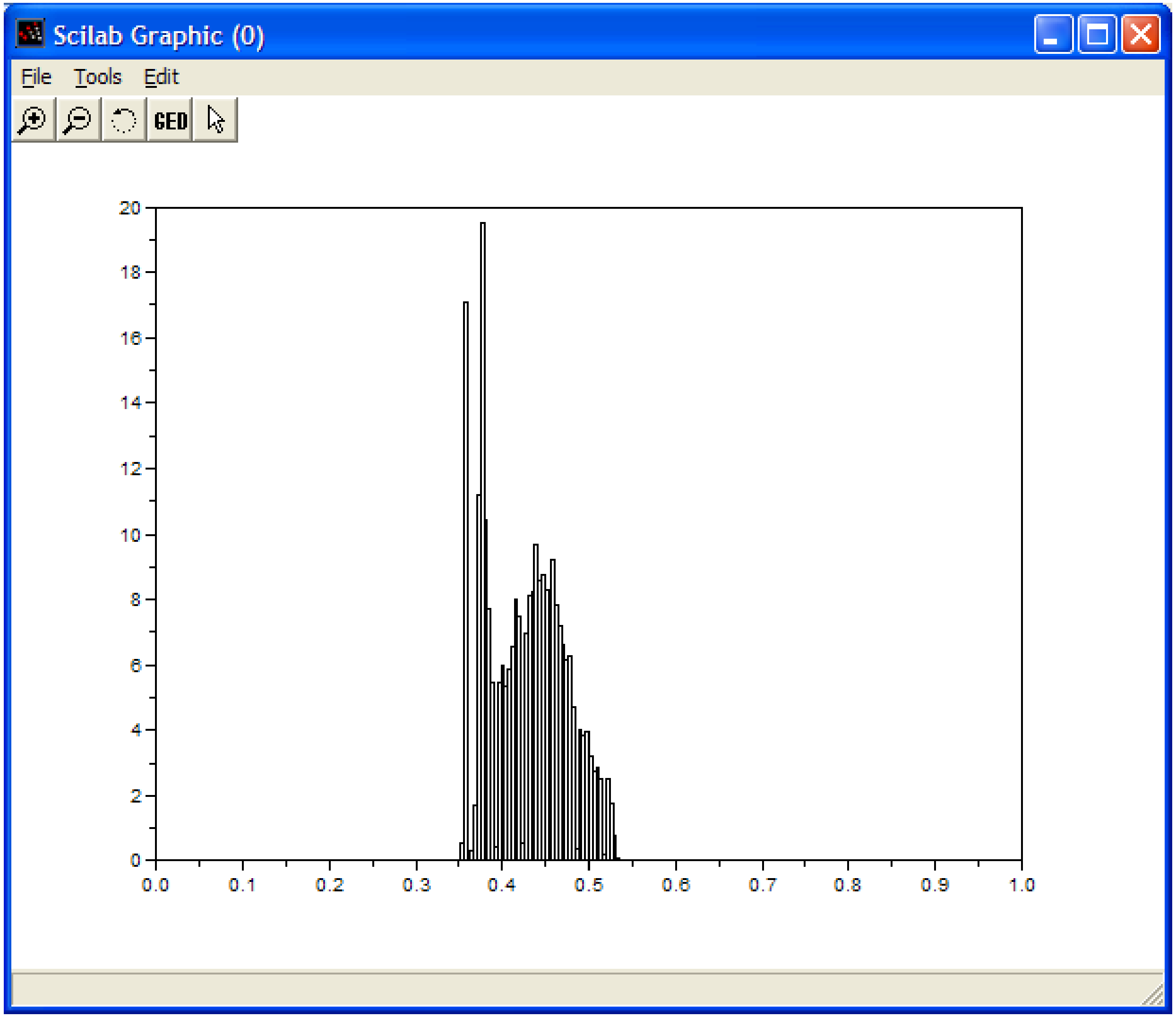


Histogram Examples (cont…)



Histogram Examples (cont…)





Histogram Examples (cont…)

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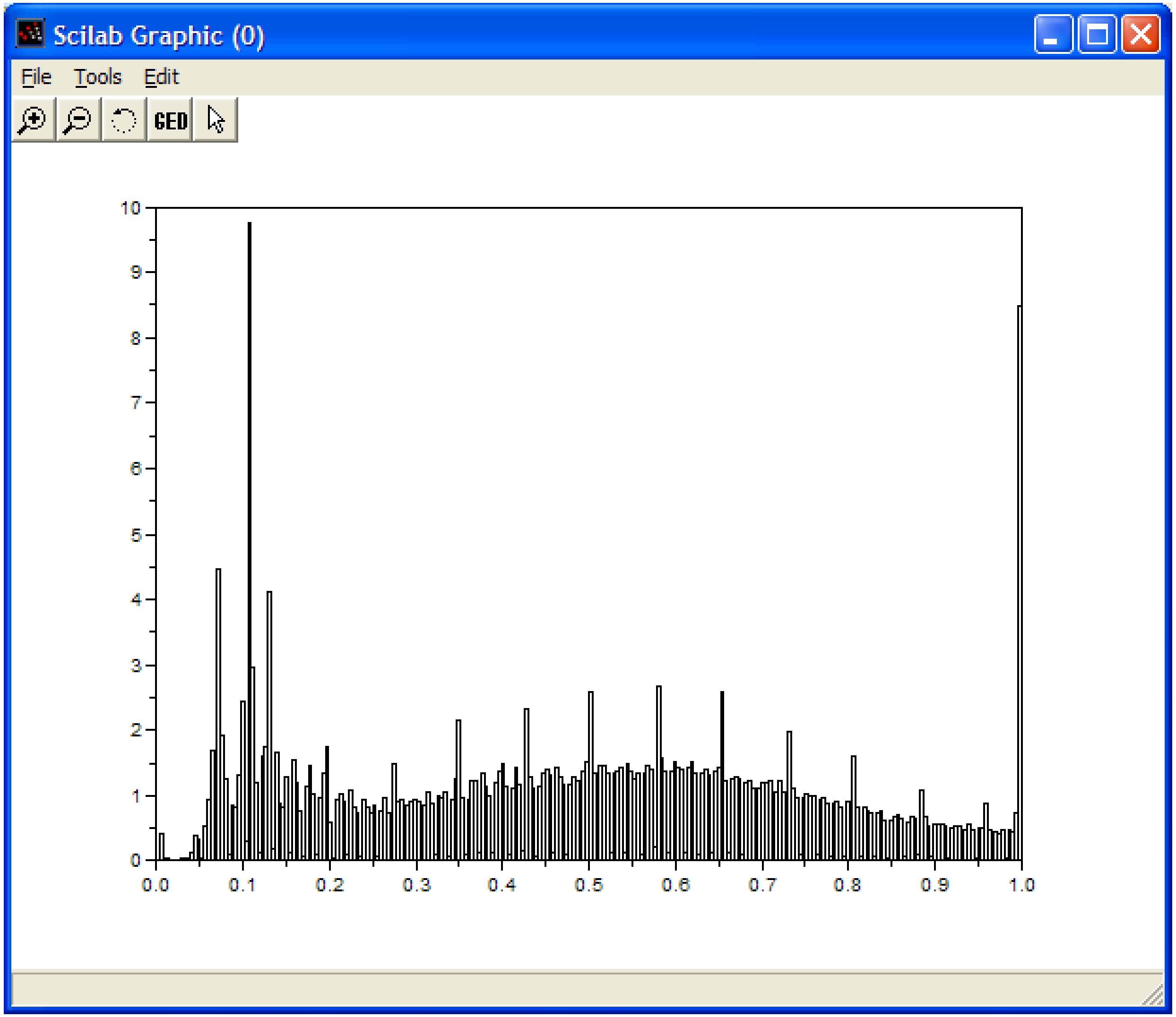


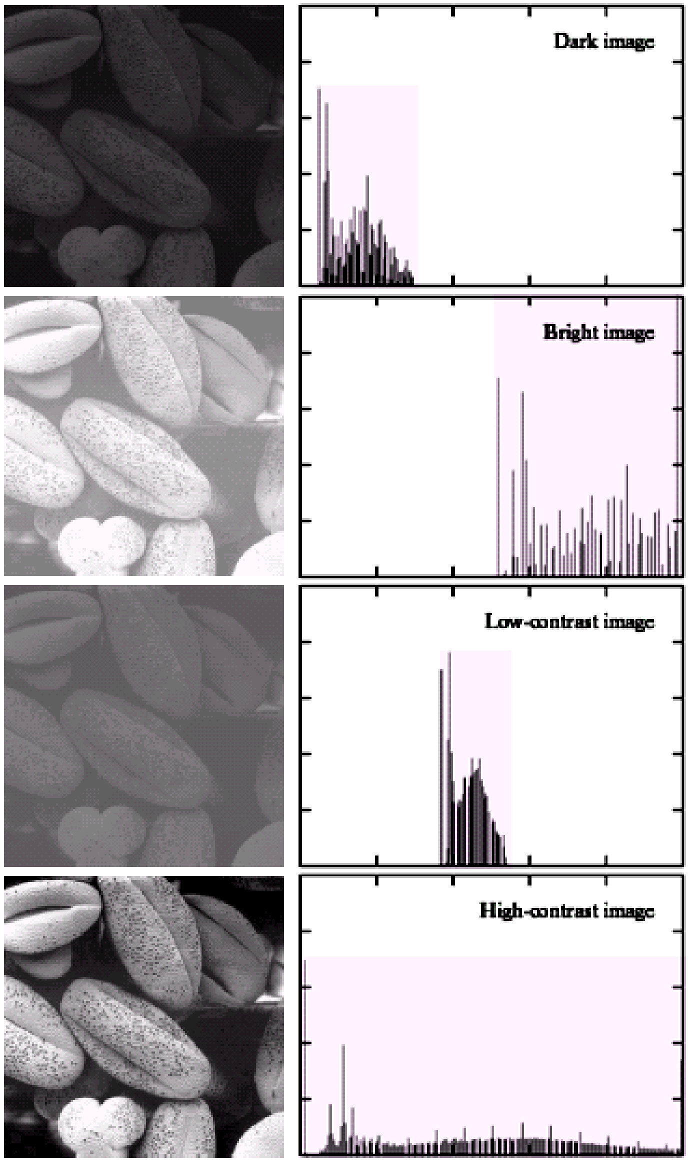
Histogram Examples (cont…)

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

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

Can be expressed as a transformation of histogram

$$s_k = T(r_k)$$

Where:

- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)

Histogram Equalisation

Let the variable r represent the gray levels of the image to be enhanced, with r=0 representing black and r=1 representing white.

For any r, the following transformations produce a level s for every pixel value r in the original image.

$$s = T(r) \qquad 0 \le r \le 1$$

The transformation function T(r) satisfies the following condition:

(a) T(r) is a single-valued and monotonically increasing in the interval $0 \le r \le 1$

(b) $0 \le T(r) \le 1$ for $0 \le r \le 1$

Histogram Equalisation

- The requirement in (a) that T(r) be single valued is needed to guarantee that the inverse transformation will exist, and monotonicity condition preserves the increasing order from black to white in the output image.

- i.e. A pixel which is darker in the original image should remain darker in the processed image, and a pixel which is brighter in the original should remain brighter in the processed image.

Histogram Equalisation

- Condition (b) guarantees that the output gray levels will be in the same range as the input levels.
- i.e. Ensure that the processed image that you get doesn’t lead to a pixel value which is higher than the max. intensity value that is allowed.

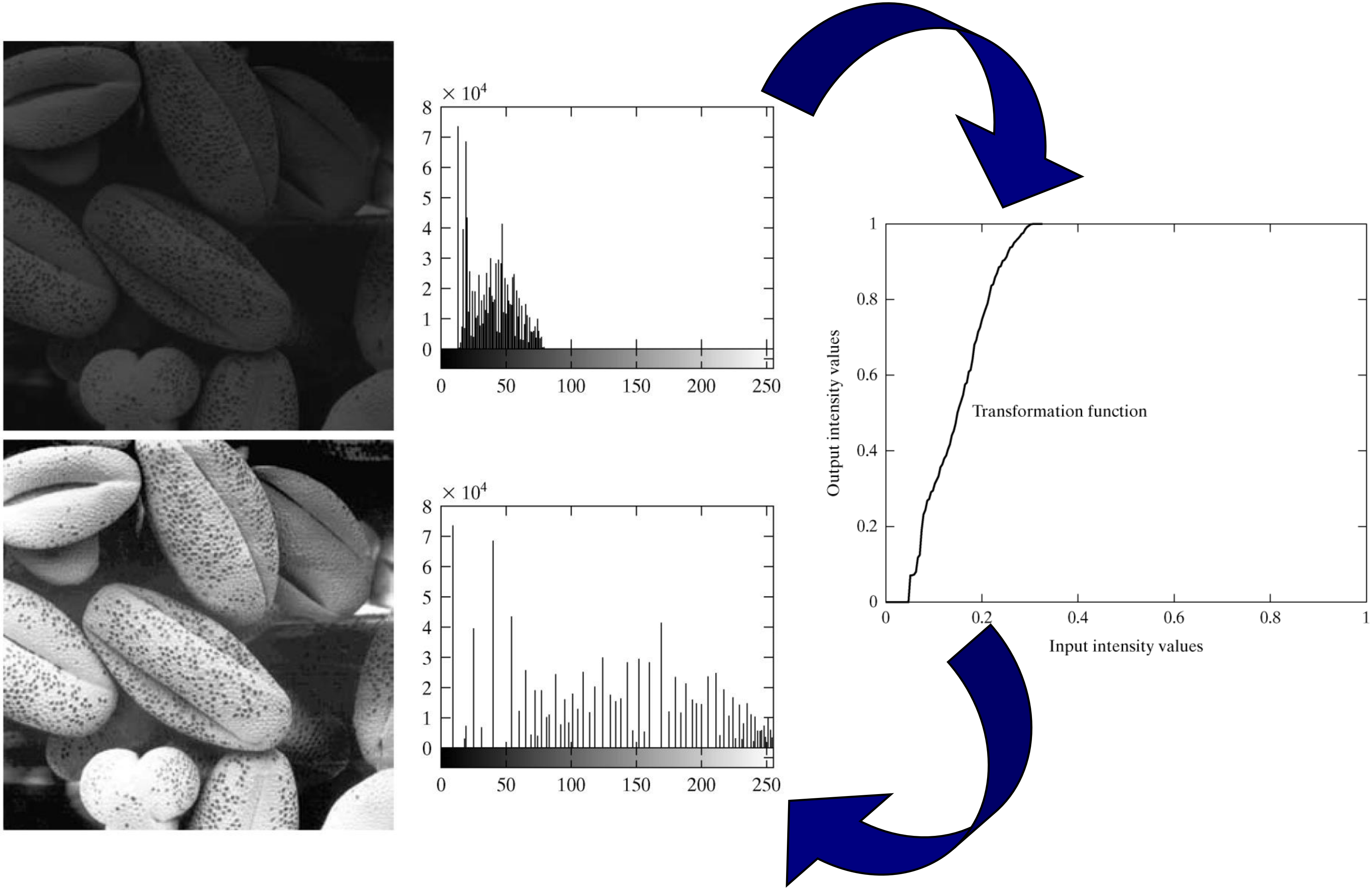
Histogram Equalisation

The formula for histogram equalisation is given where

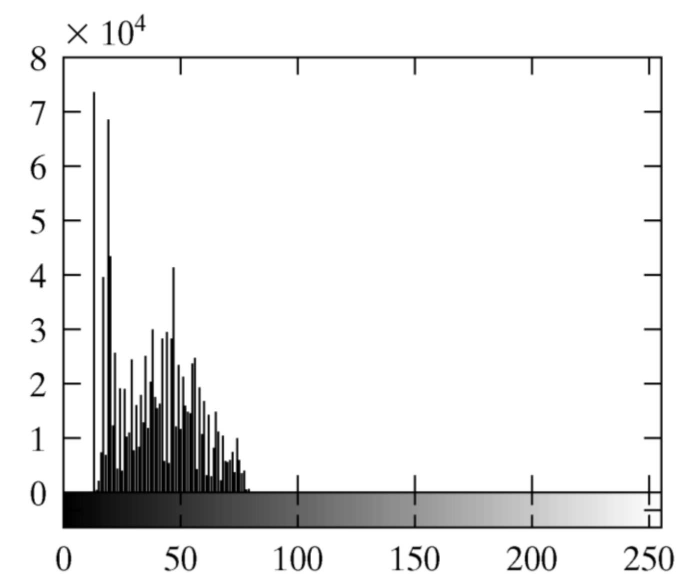
- r_k: input intensity
- s_k: processed intensity
- k: the intensity range (e.g 0.0 – 1.0)
- n_j: the frequency of intensity j
- n: the sum of all frequencies

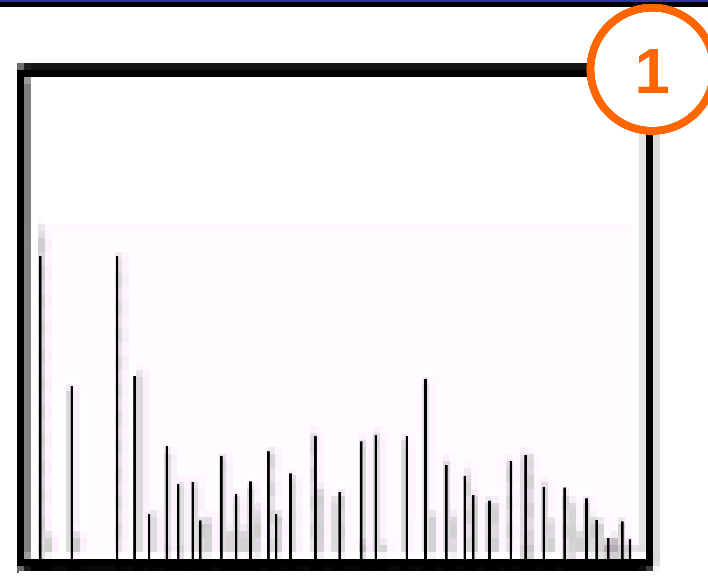
$$
\begin{aligned}
s_k &= T(r_k) \\
&= \sum_{j=1}^{k} p_r(r_j) \\
&= \sum_{j=1}^{k} \frac{n_j}{n}
\end{aligned}
$$

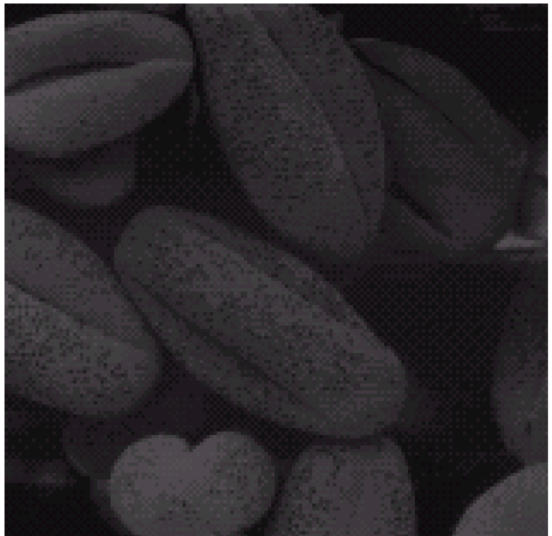
Equalisation Transformation Function



Equalisation Examples



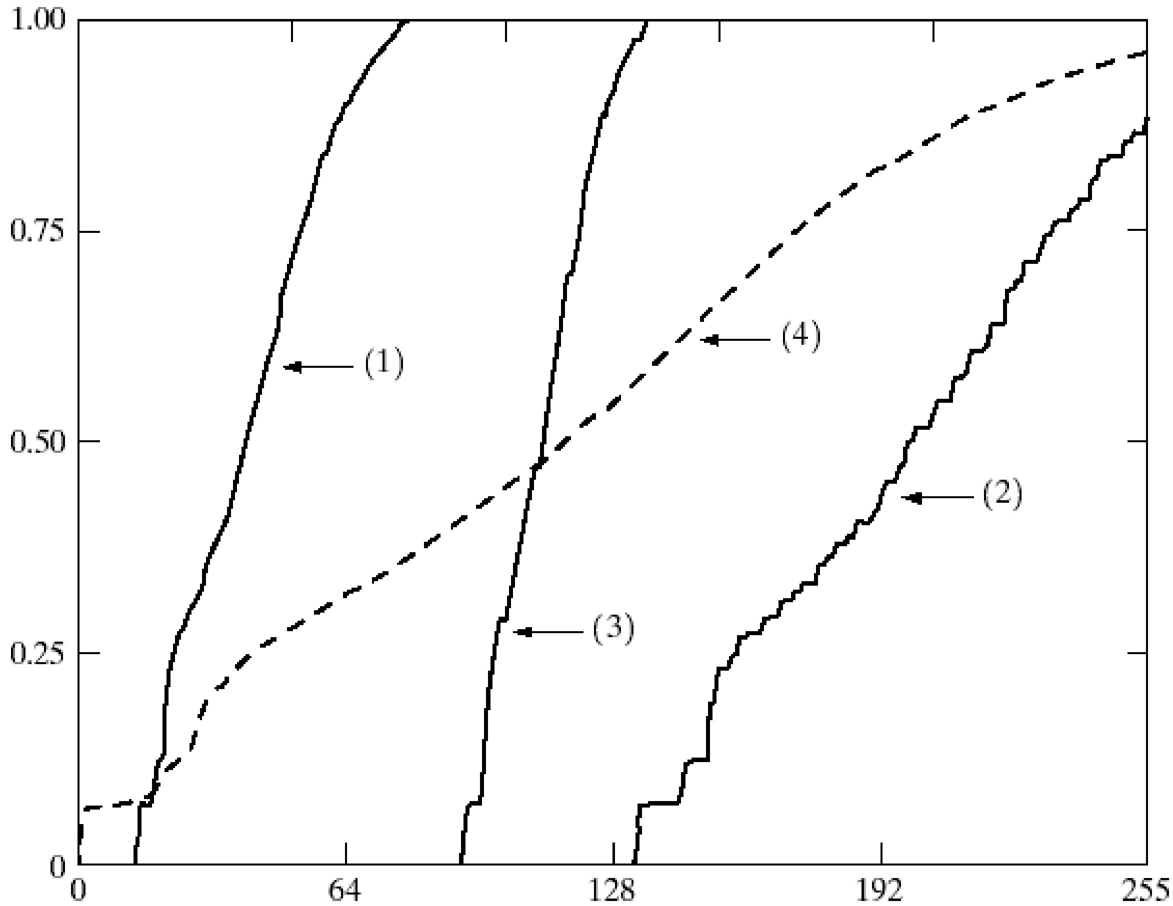




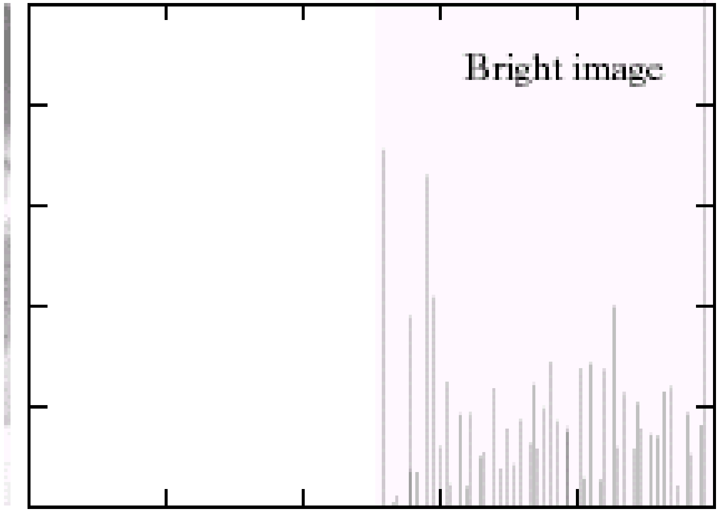
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

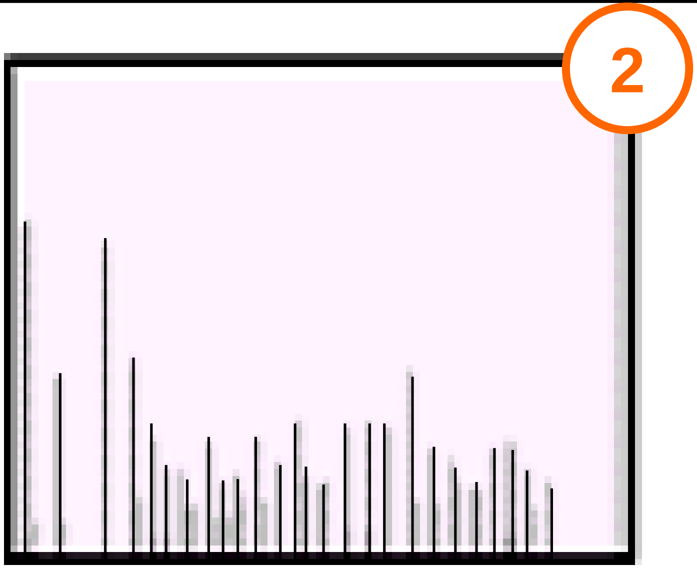
Equalisation Transformation Functions

The functions used to equalise the images in the previous example



Equalisation Examples





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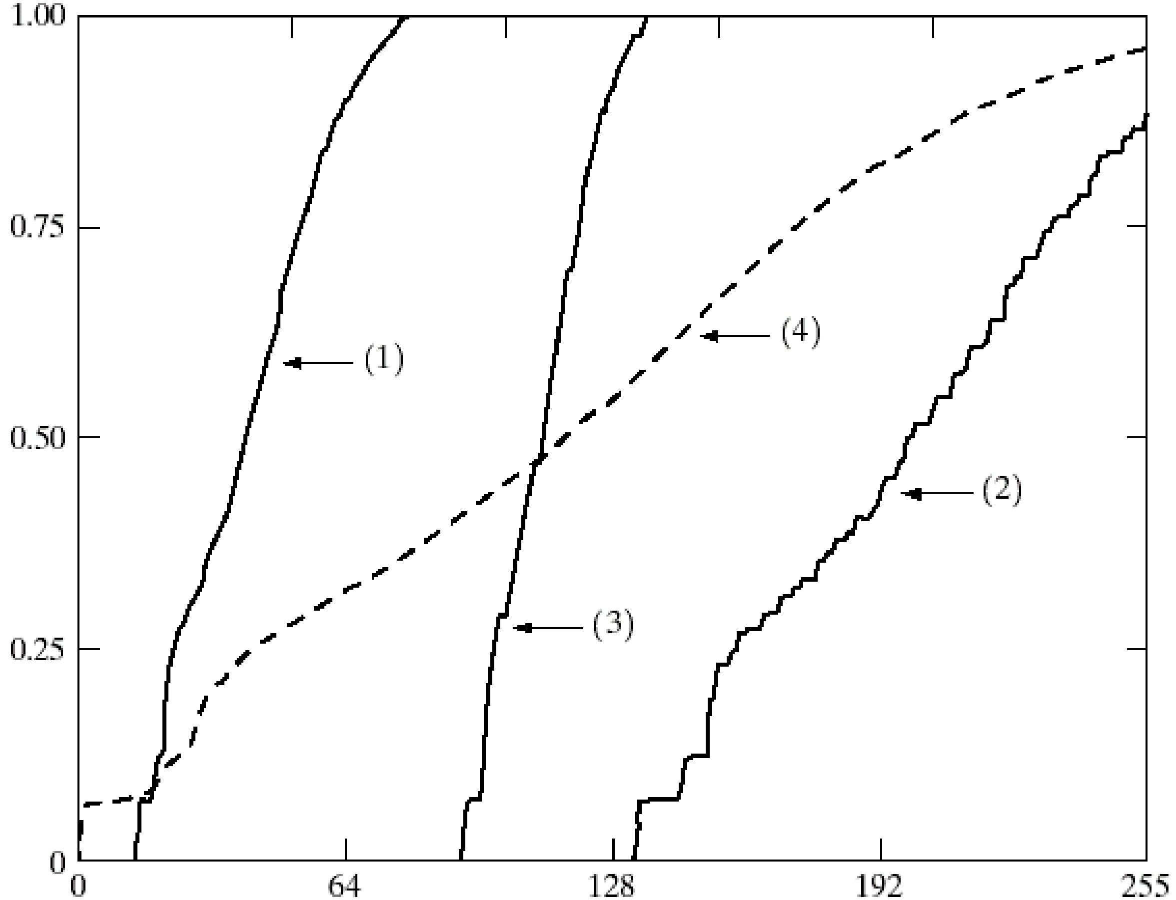
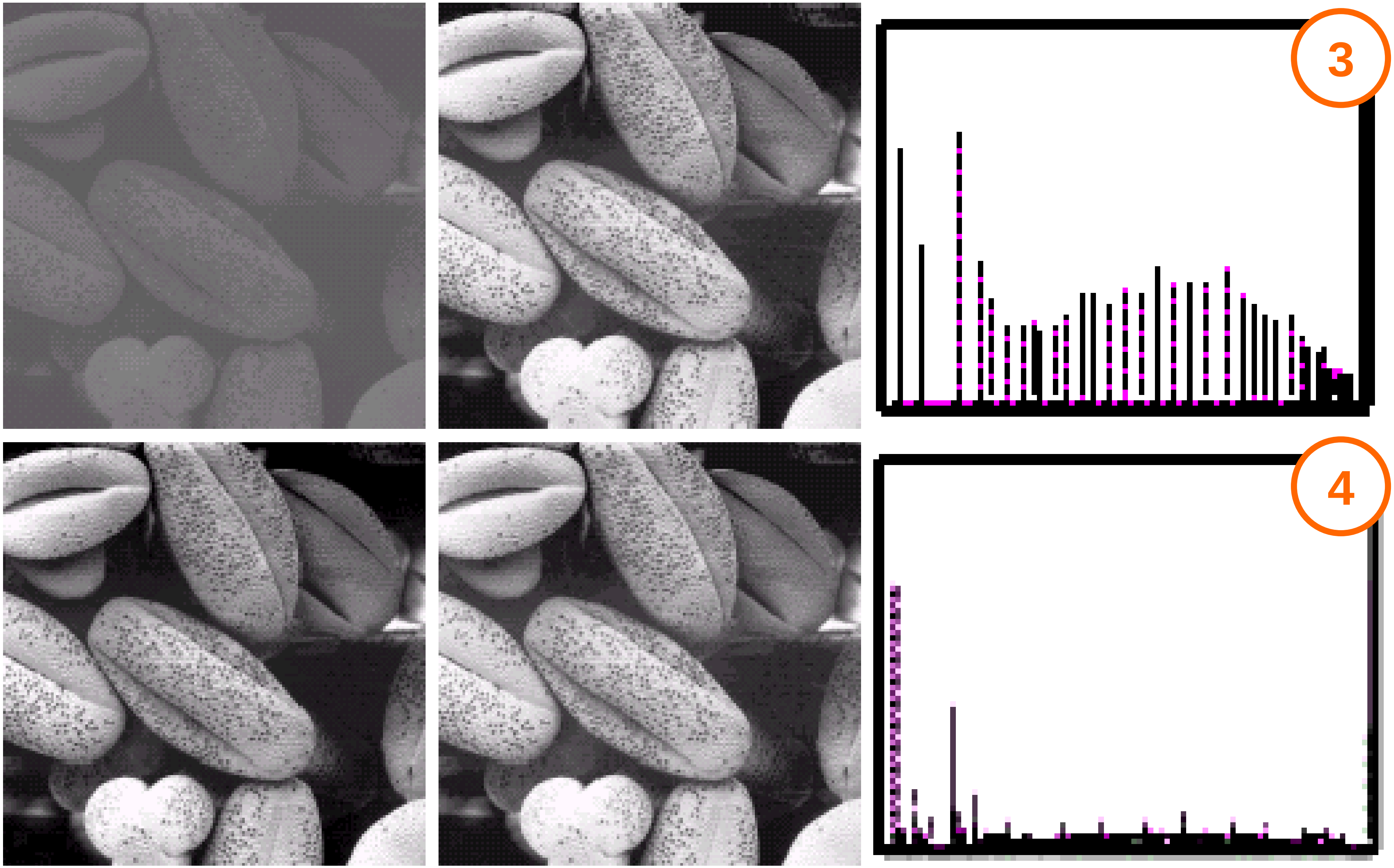
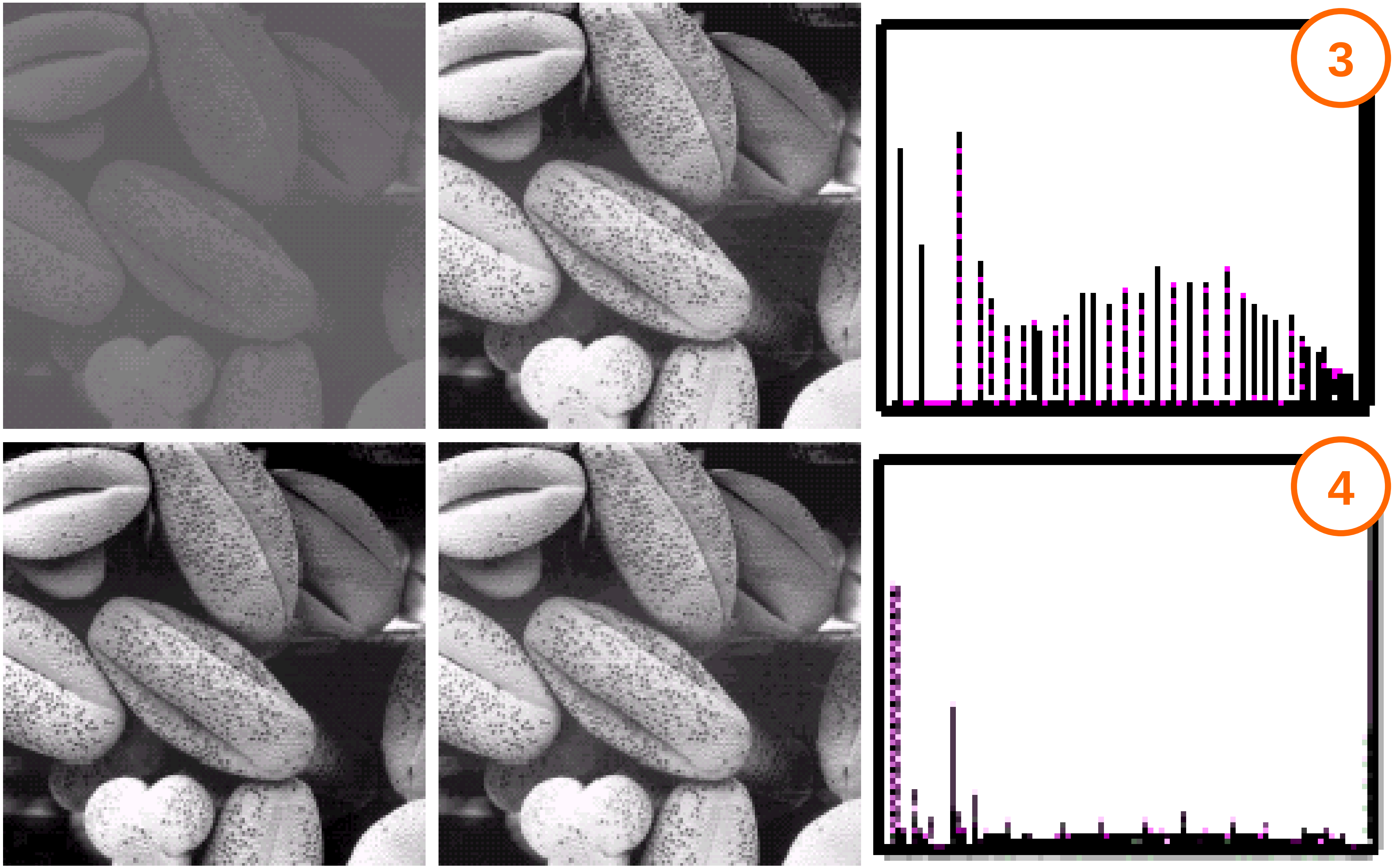


Equalisation Examples (cont…)



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

Equalisation Examples (cont…)



Equalisation Transformation Functions

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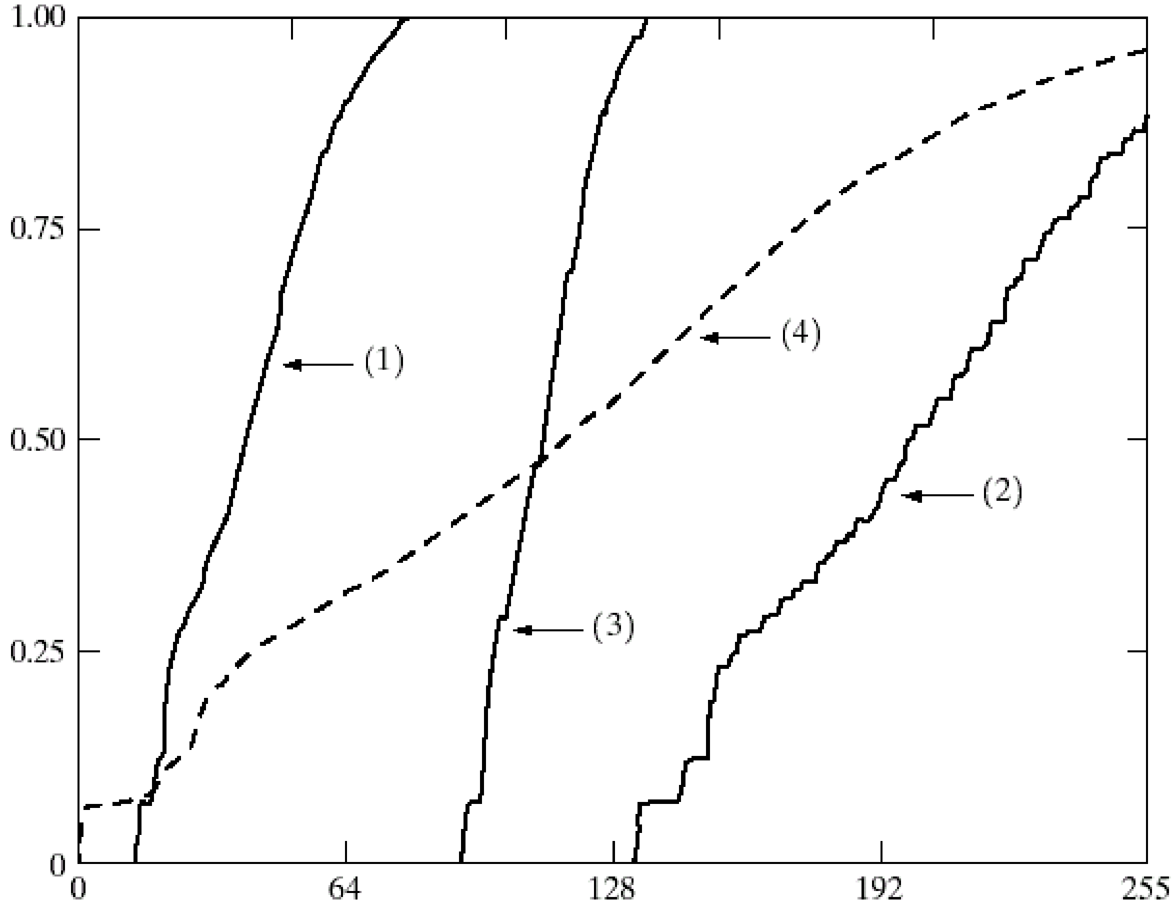

Quiz

1. Histogram equalization proof.

2. Exposure?

a. Underexposed

b. Properly Exposed

c. Overexposed

Summary

We have looked at:

- Different kinds of image enhancement
- Histograms
- Histogram equalisation

Next time we will start to look at point processing and some neighbourhood operations