Image Enhancement

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Visão por Computador

Contents

This lecture will cover:

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

Note about Grey Levels

- **Grey level values** 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] => **Normalization**

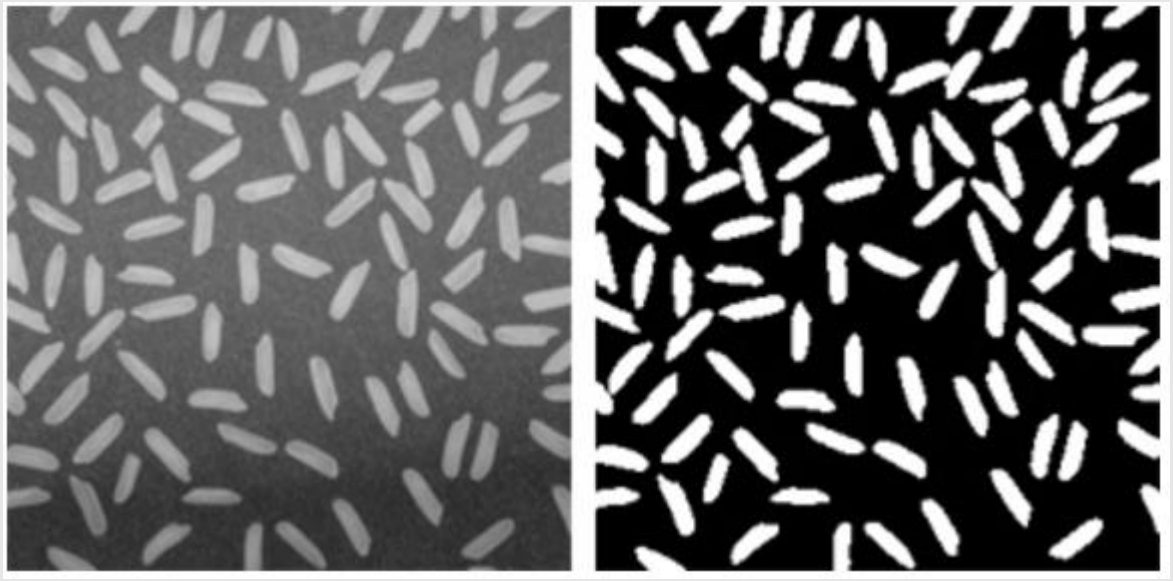
- **Binary image** can take only two value (0 or 255)

What is Image Enhancement?

- **Image enhancement** is the process of adjusting digital images so that the results are more suitable than the original image;

- The reasons for doing this include:
  - Highlighting interesting detail in images
  - Removing noise from images
  - Making images more visually appealing

Image Enhancement Examples



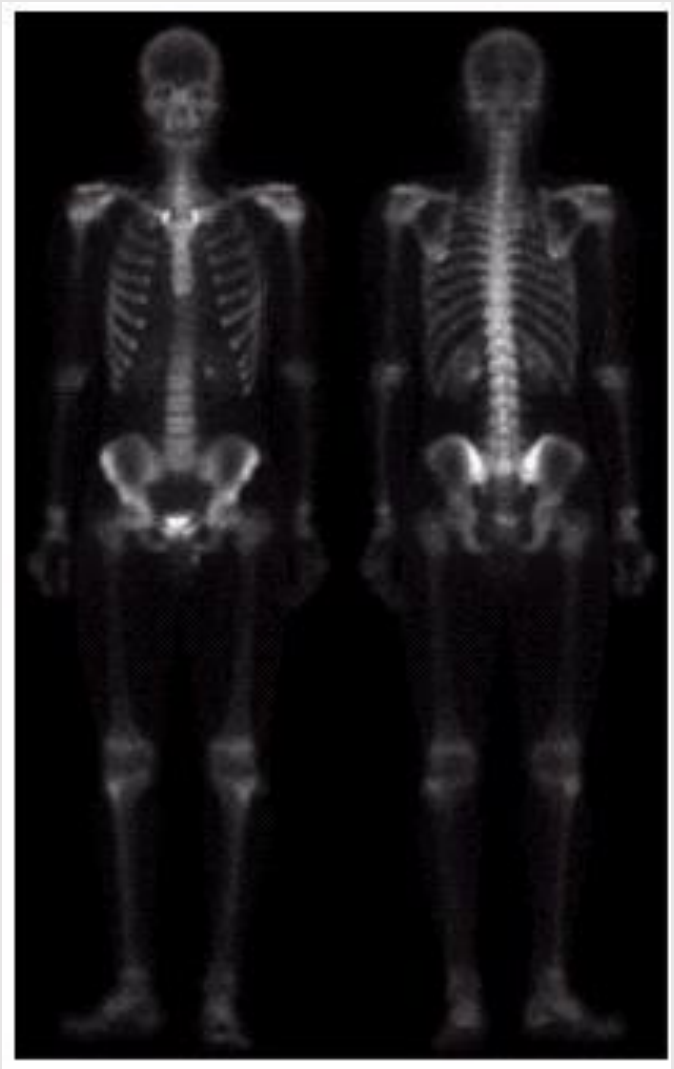
Correcting nonuniform illumination with **morphological operator**

Enhancing grayscale images with **histogram equalization**

Image Enhancement Examples

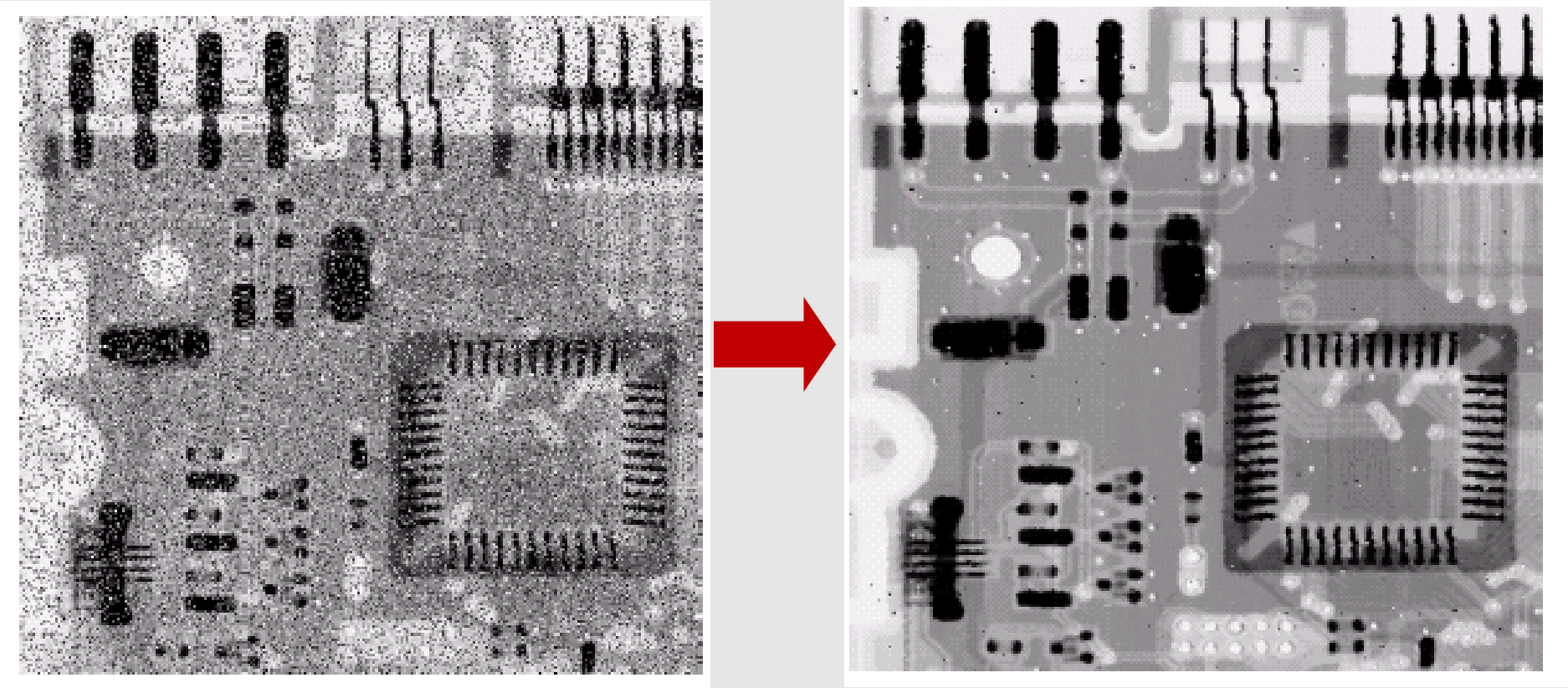
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Enhancement Examples



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

Image Enhancement Examples



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

Image Enhancement

The **image enhancement techniques** can be divided into two broad categories:

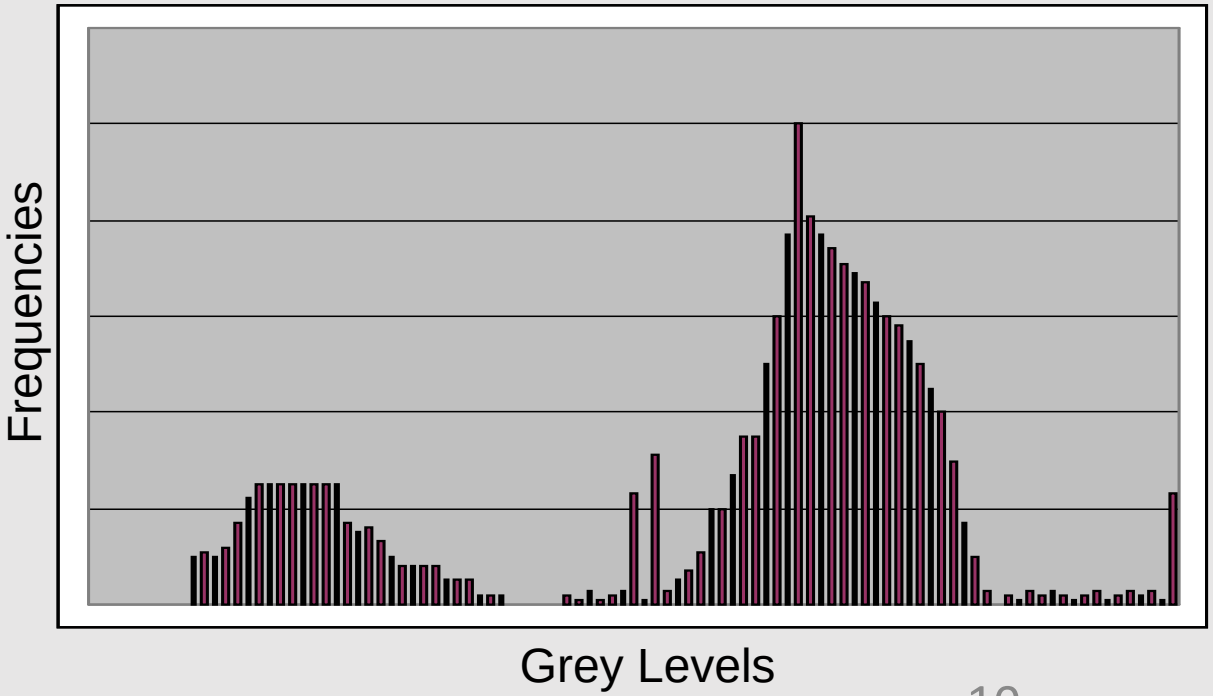
- **Spatial domain methods**: direct manipulation of image pixels;
- **Frequency domain methods**: manipulation of Fourier transform or wavelet transform of an image;

Image Histogram

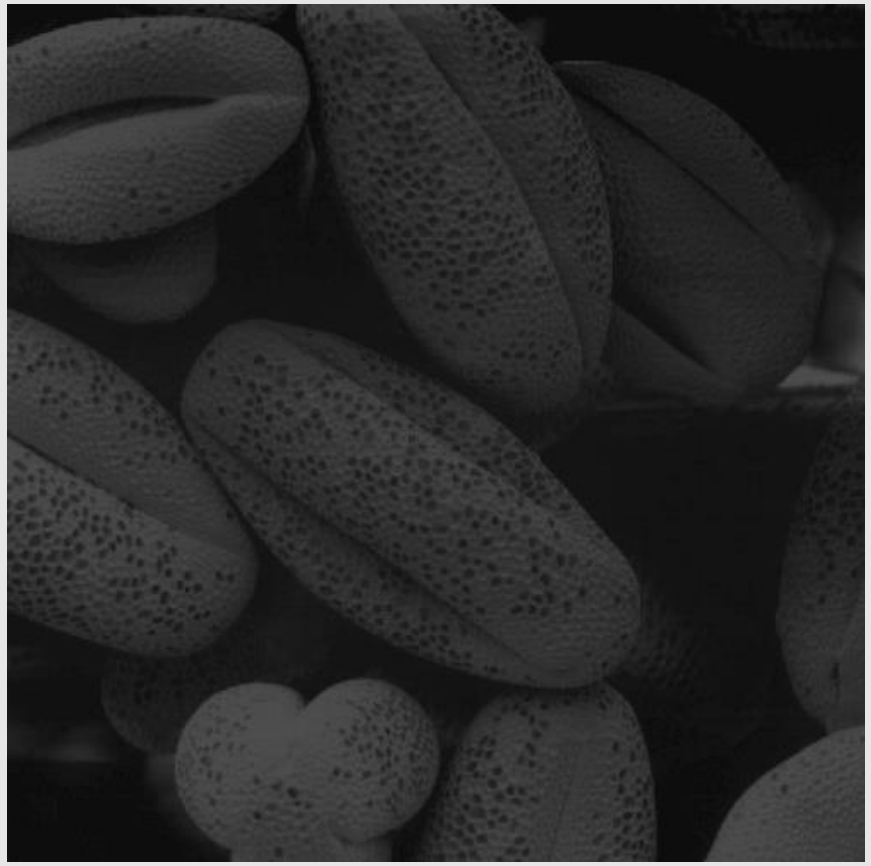
- The histogram of an image shows us the distribution of grey levels in the image, i.e., indicate us the number of pixels for each intensity of grey level;

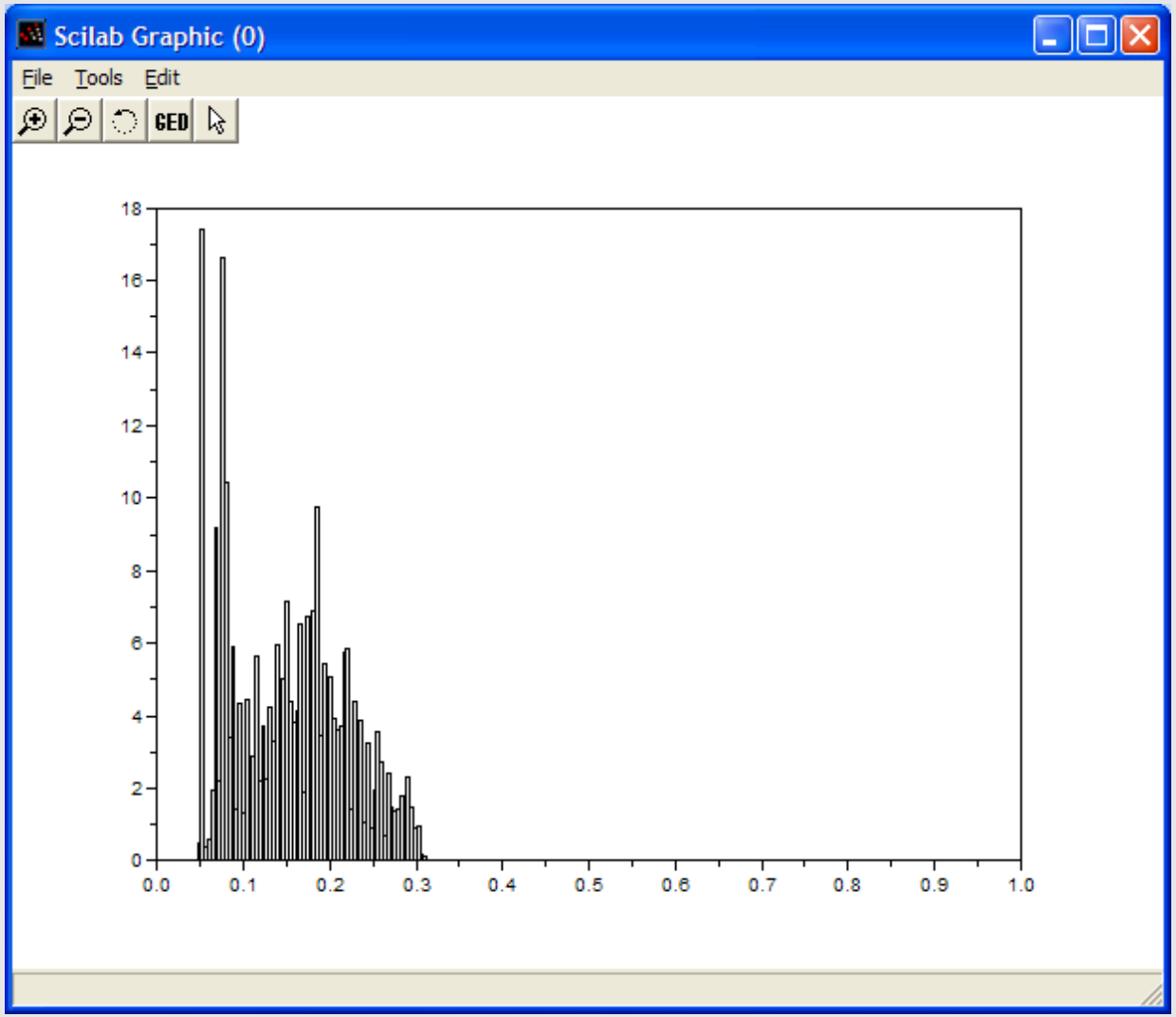
- By viewing the image's histogram, we can analyze the frequency of appearance of the different grey levels contained in the image.

- A good histogram is that which covers all the possible values in the grey scale used => suggests that the image has good contrast and that details in the image may be observed more easily.



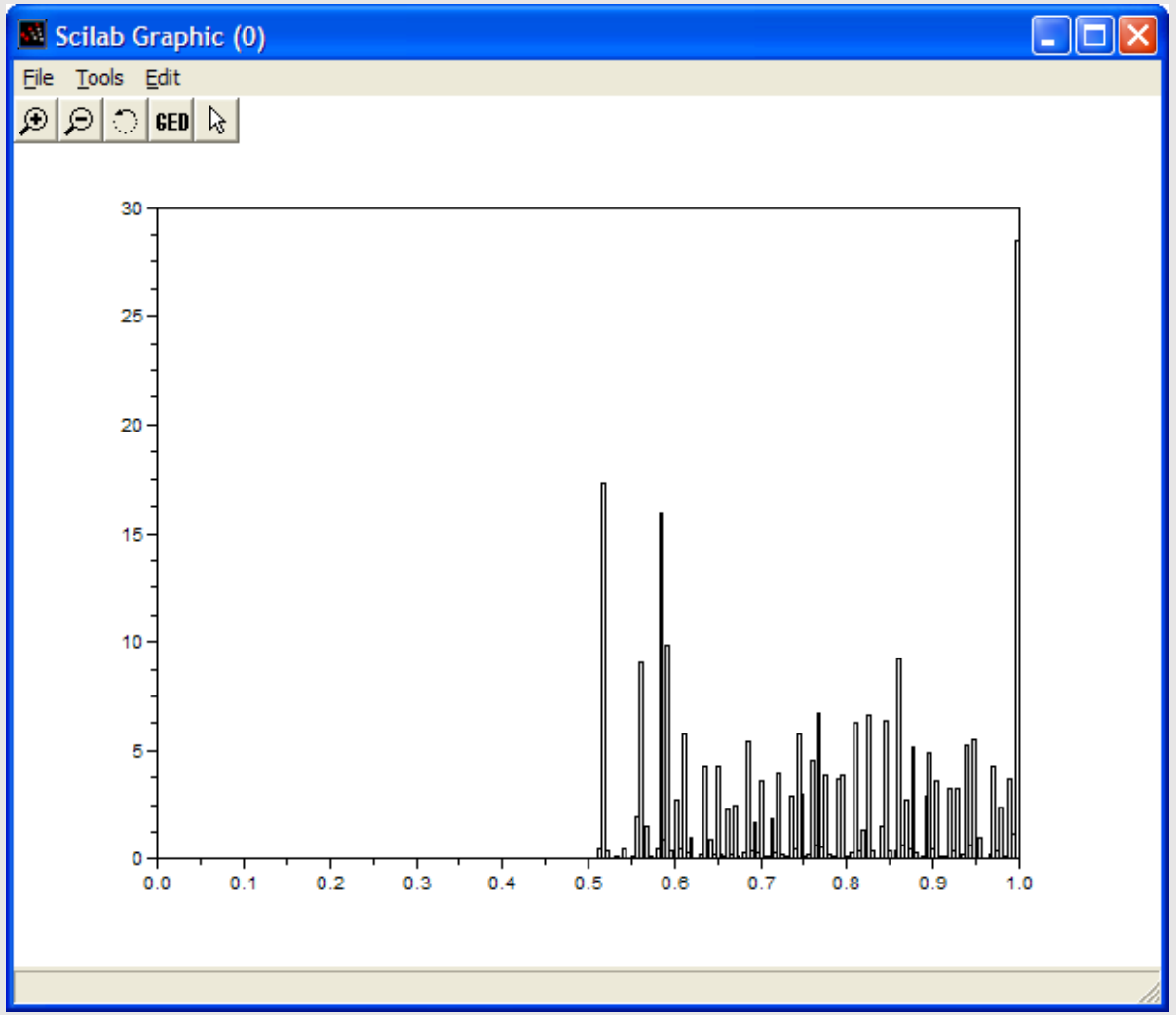
Histogram Examples





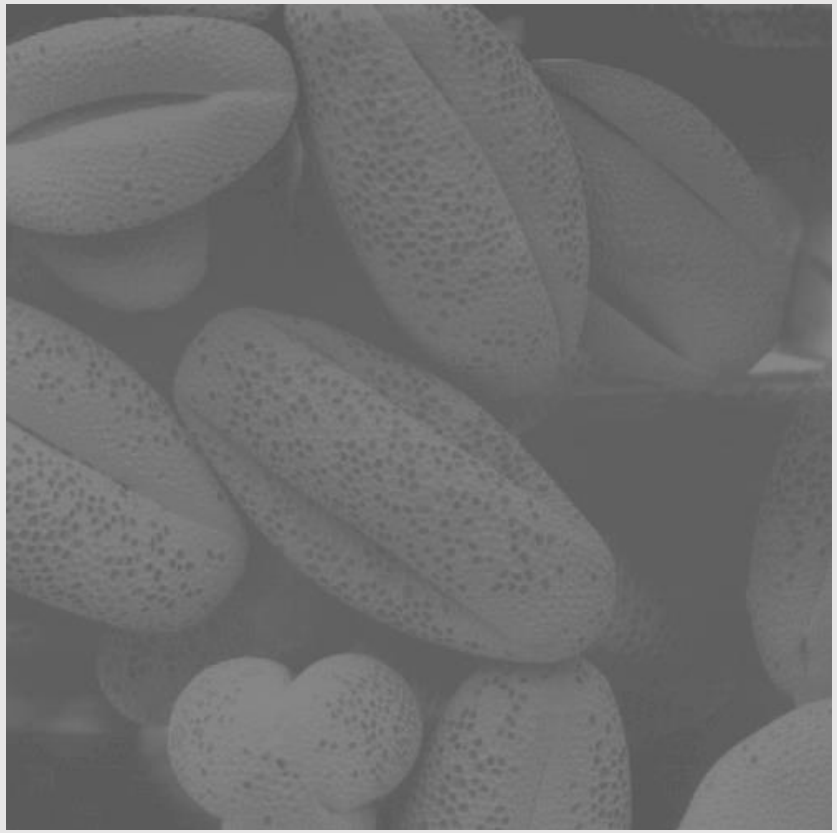
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

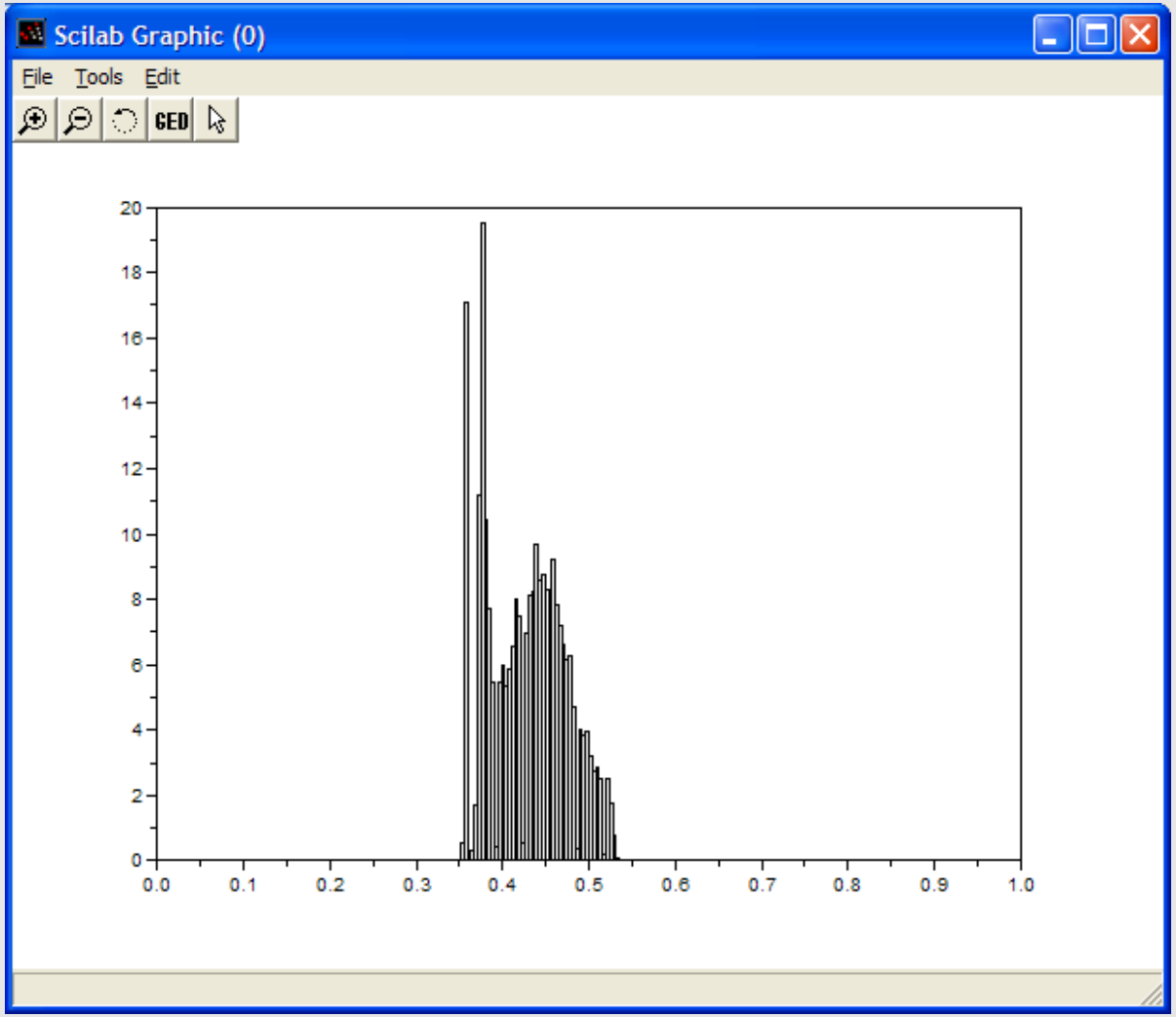
Histogram Examples



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

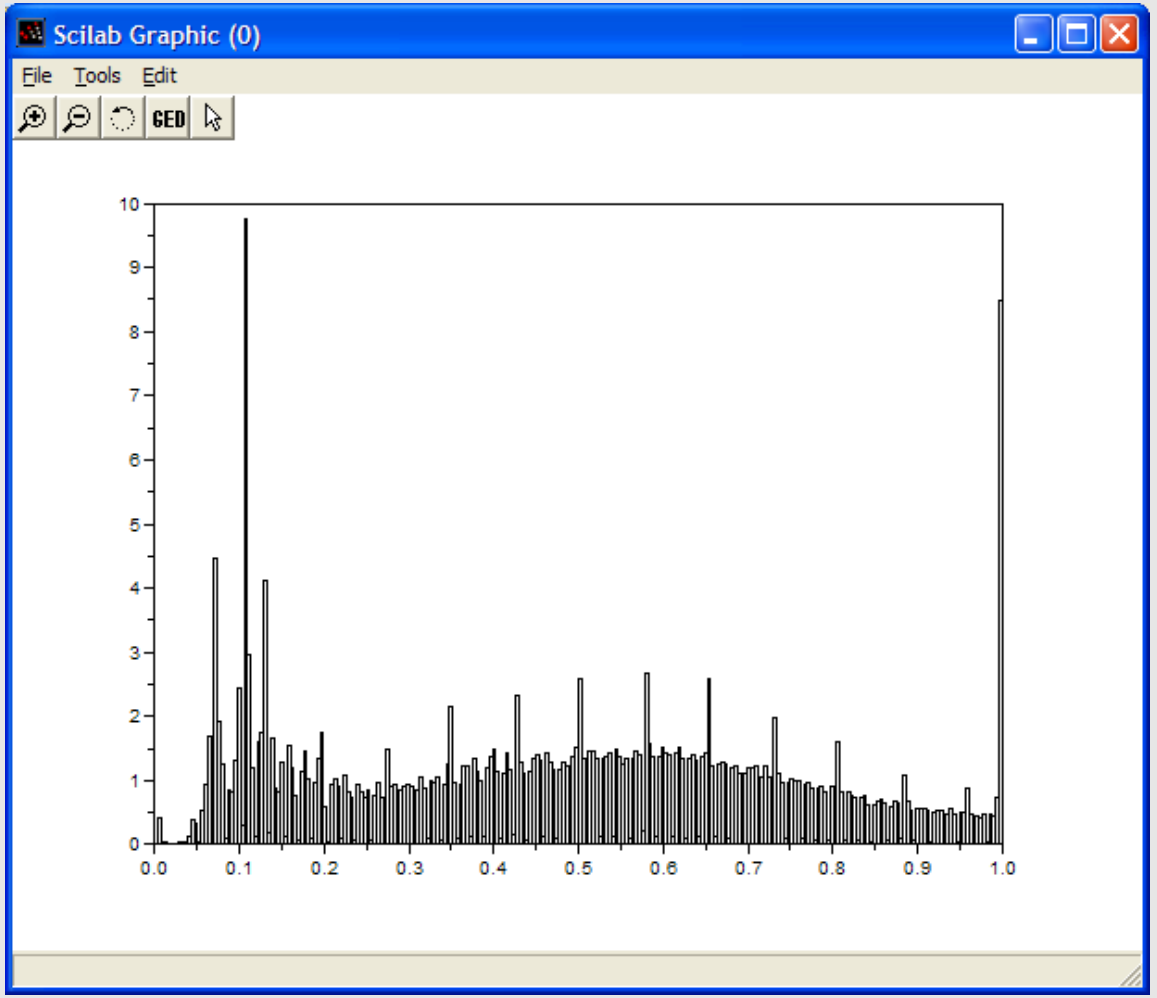
Histogram Examples





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

Histogram Examples

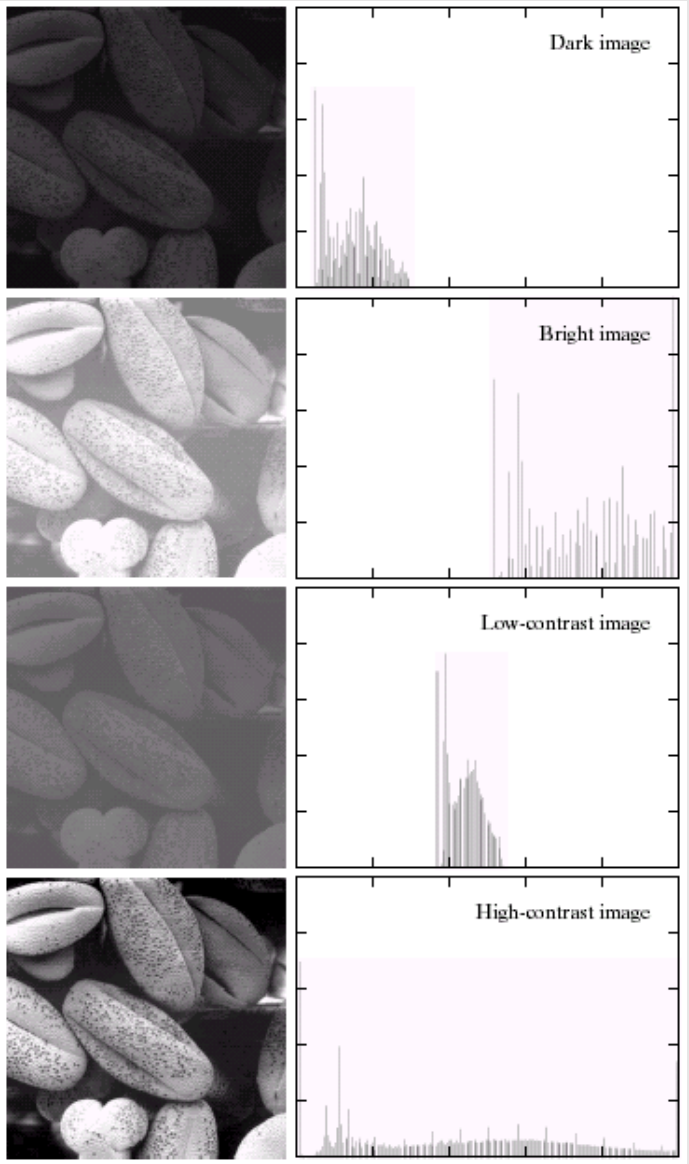


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Examples

- 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 => Better quality

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



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

Stretching vs equalization

- **Contrast** is a measure of the “range” of an image; i.e. how spread its intensities are.
- **Contrast** is strongly tied to an image’s overall visual quality it broadens the histogram of the image intensity levels, so the intensity around the range of input may be mapped to the full intensity range. Ideally, we’d like images to use the entire range of values available to them.
- **Histogram equalization** is a nonlinear normalization that stretches the area of histogram with high abundance intensities and compresses the area with low abundance intensities.
- **Contrast Stretching** and **Histogram Equalisation** have the same goal: making the images to use entire range of values available to them.
- But they use different techniques.

Stretching vs equalization

- ***Contrast stretching*** is all about increasing the difference between the maximum intensity value in an image and the minimum one. All the rest of the intensity values are spread out between this range.

  It has many formal definitions one famous is Michelson's:

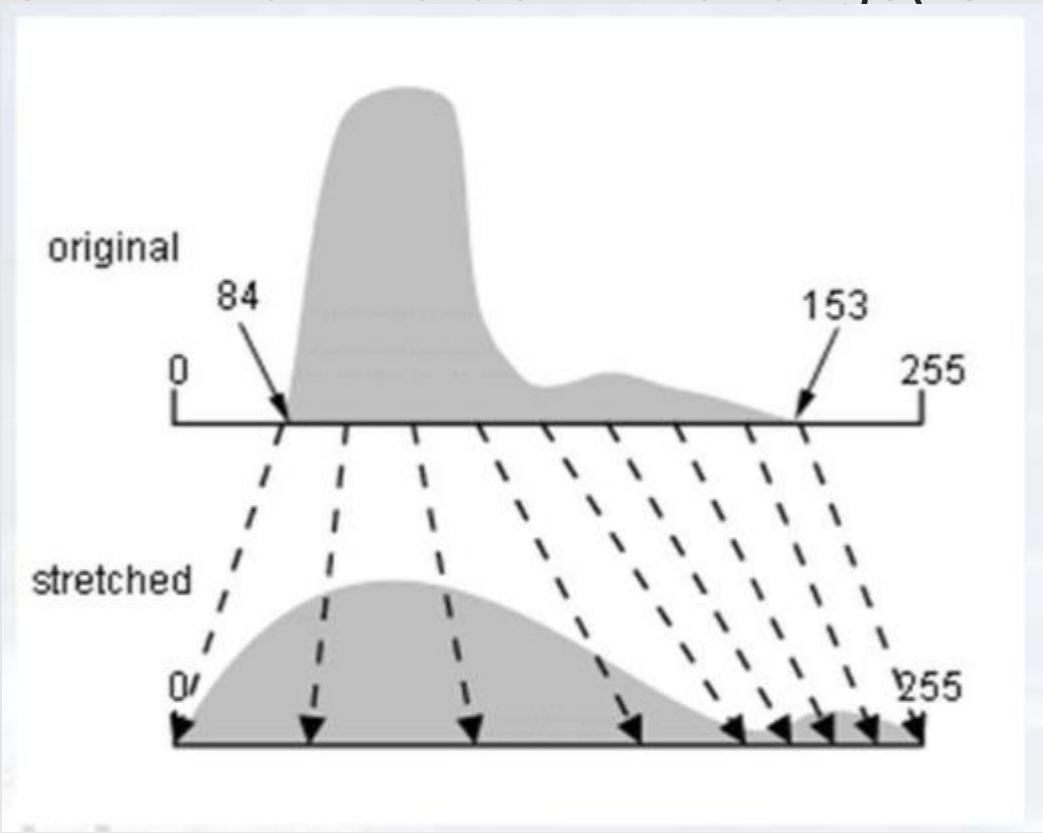
  ```
  contrast = ( Imax - Imin )/( Imax + I min )
  ```

- ***Histogram equalization*** is about modifying the intensity values of all the pixels in the image such that the histogram is "flattened" (in reality, the histogram can't be exactly flattened, there would be some peaks and some valleys, but that's a practical problem).

In ***contrast stretching***, there exists a one-to-one relationship of the intensity values between the source image and the target image i.e., the original image can be restored from the contrast-stretched image.
In ***histogram equalization*** there is no way of getting back the original image.

Contrast Stretching

- **Contrast Stretching** works like mapping, like in normalization
- it maps **minimum intensity** in the image to the **minimum value** in the range(84 ==> 0 in the example)
- it maps **maximum intensity** in the image to the **maximum value** in the range (153 ==> 255 in the example)
- This is why Contrast Stretching is **un-reliable**, if there exist only two pixels with 0 and 255 intensity, it is totally useless.



Histogram Equalisation

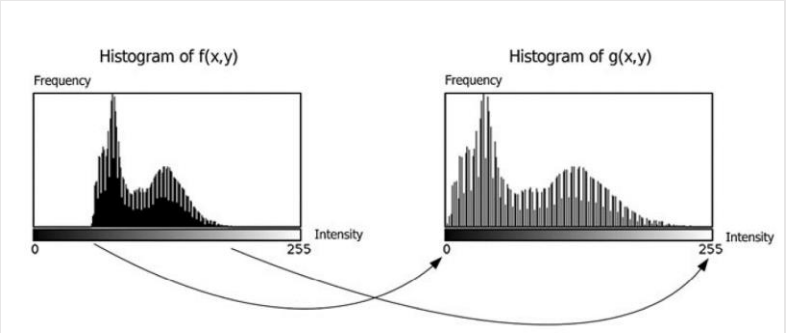
- Spreading out the frequencies in an image (or equalising the image) in the attempt to enhance the contrast;
  => Proper distribution of the image for the available grey levels

- **Histogram equalization** involves **transforming the intensity values** so that the histogram of the resulting image is equalized to become a constant;

- This technique can be used on a whole image or just on a part of an image;

Note

During histogram equalization the overall shape of the histogram changes, where as in histogram stretching the overall shape of histogram remains same



Histogram stretching

Histogram Equalisation

- The formula for histogram equalisation is

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

k: the intensity range (e.g 0-255)

r_k: input intensity

s_k: processed intensity = image's histogram for pixel value *k* normalized to [0,1].

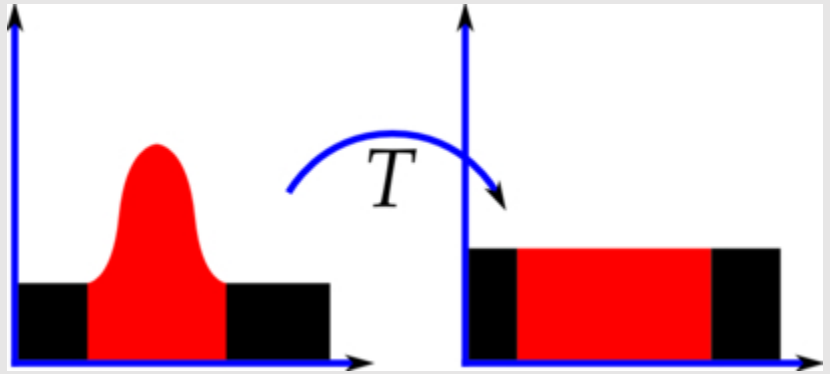
n_j: the frequency of intensity *j*

n: the sum of all frequencies

T: transformation of pixel intensities

Histogram Equalization

Histogram equalization maps all of the pixels to the full range according to the cumulative distribution function or probability.
In Histogram equalization, you want to flatten the histogram into a uniform distribution.



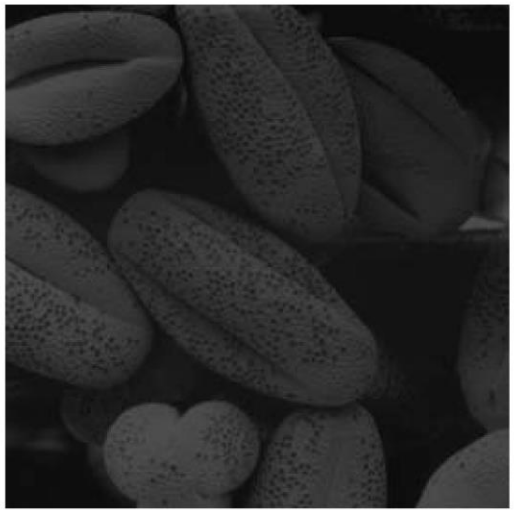
- **Histogram equalization** is a nonlinear normalization that stretches the area of histogram with high abundance intensities and compresses the area with low abundance intensities.

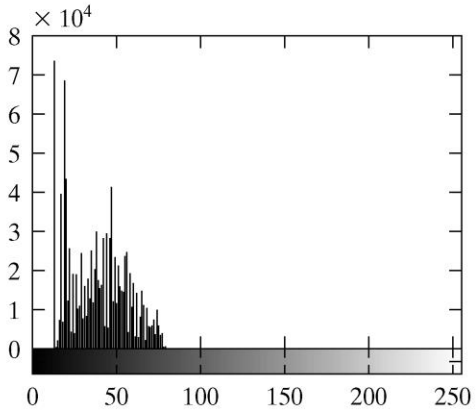
Methods for Histogram Equalisation

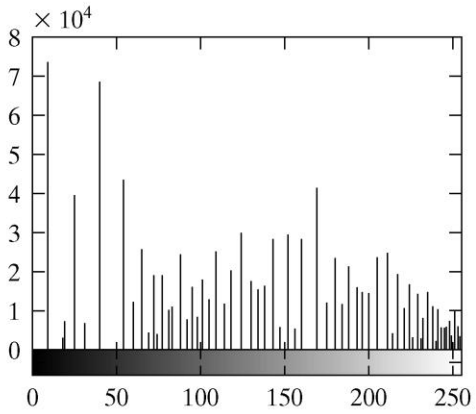
Method	Advantage	Disadvantage
Histogram expansion	Simple and enhance contrasts of an image.	If there are gray values that are physically far apart from each other in the image, then this method fails.
LAHE	Offers an excellent enhancement of image contrast.	Computationally very slow, requires a high number of operations per pixel.
Cumulative histogram equalization	Has good performance in histogram equalization.	Requires a few more operations because it is necessary to create the cumulative histogram.
Par sectioning	Easy to implement.	Better suited to hardware implementation.
Odd sectioning	Offers good image contrast.	Has problems with histograms which cover almost the full gray scale.

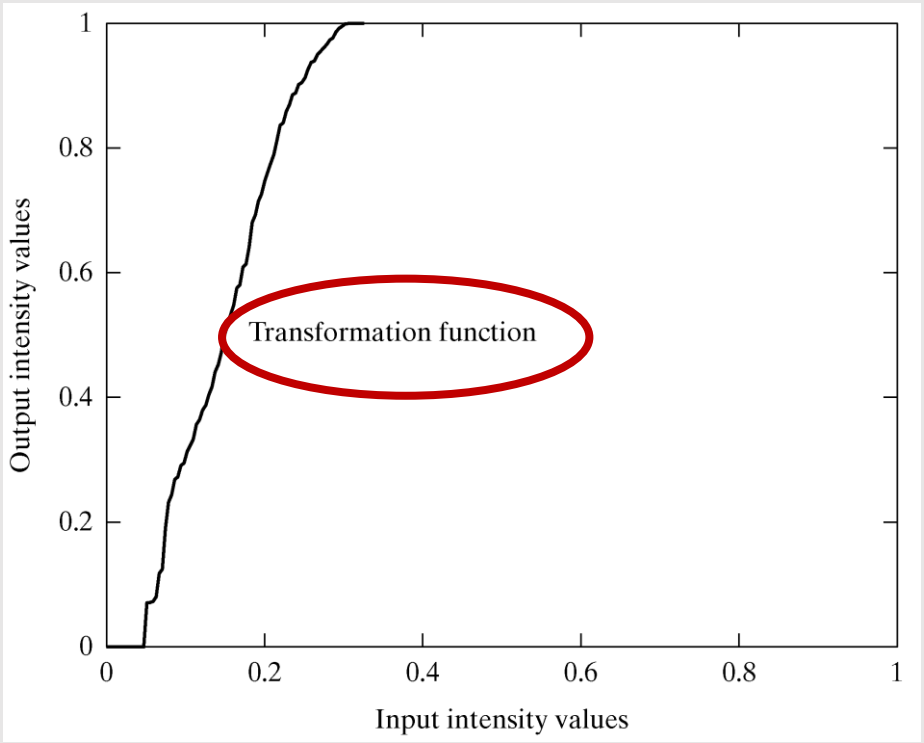
Cumulative histograma equalisation algorithm is usually selected due to its good performance and easy implementation ✓

Histogram Equalisation Examples



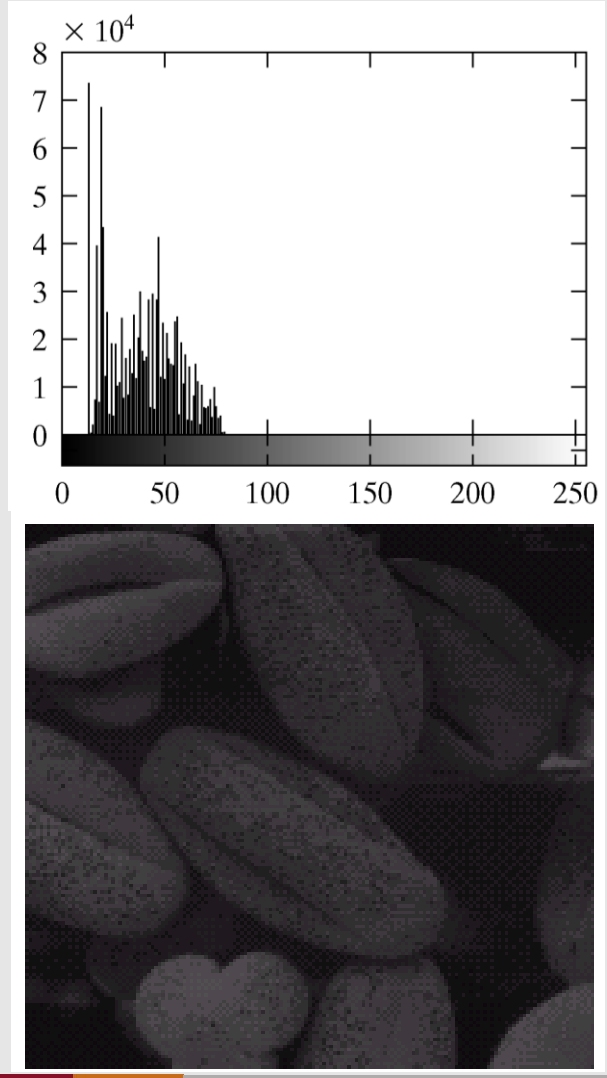


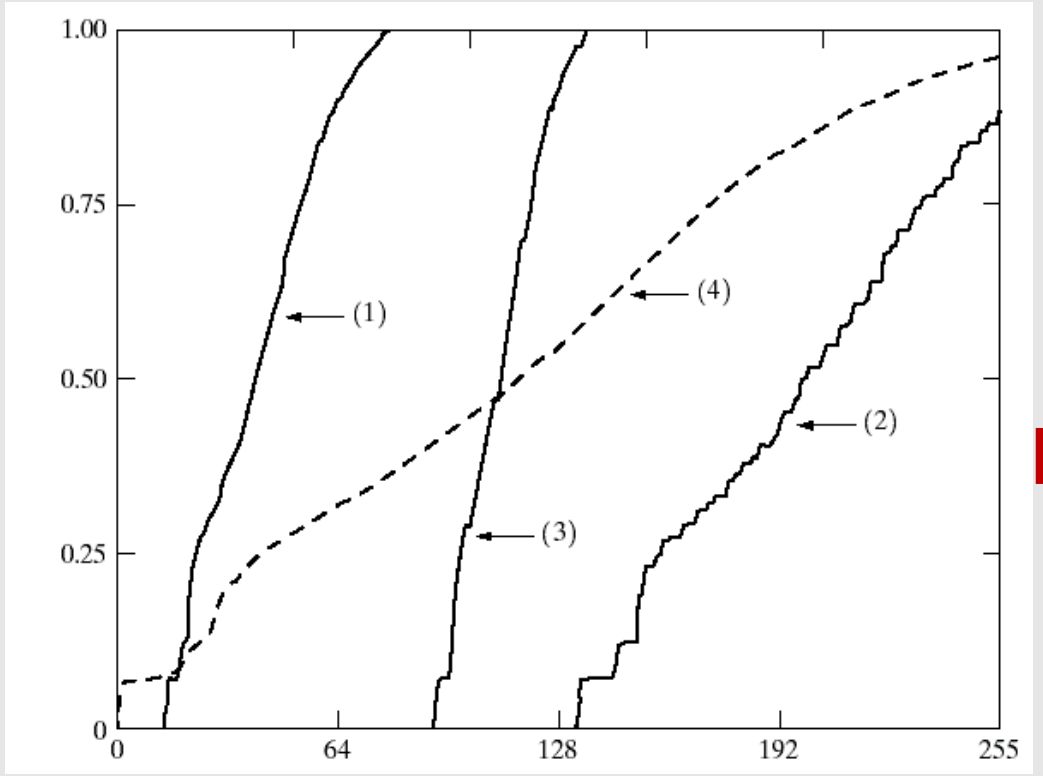


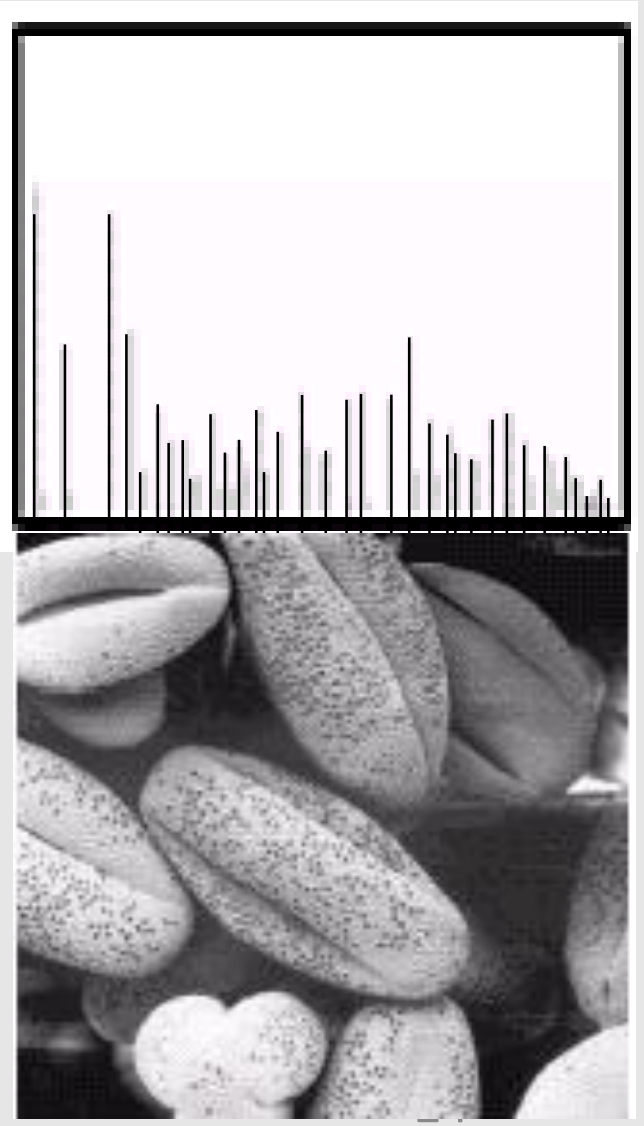


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Histogram Equalisation Examples

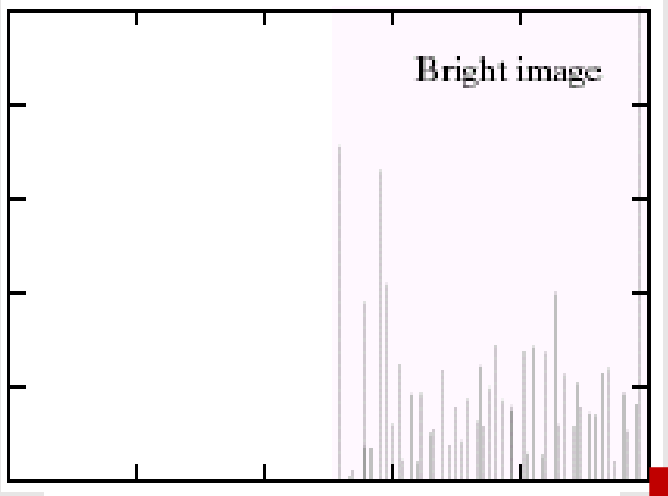


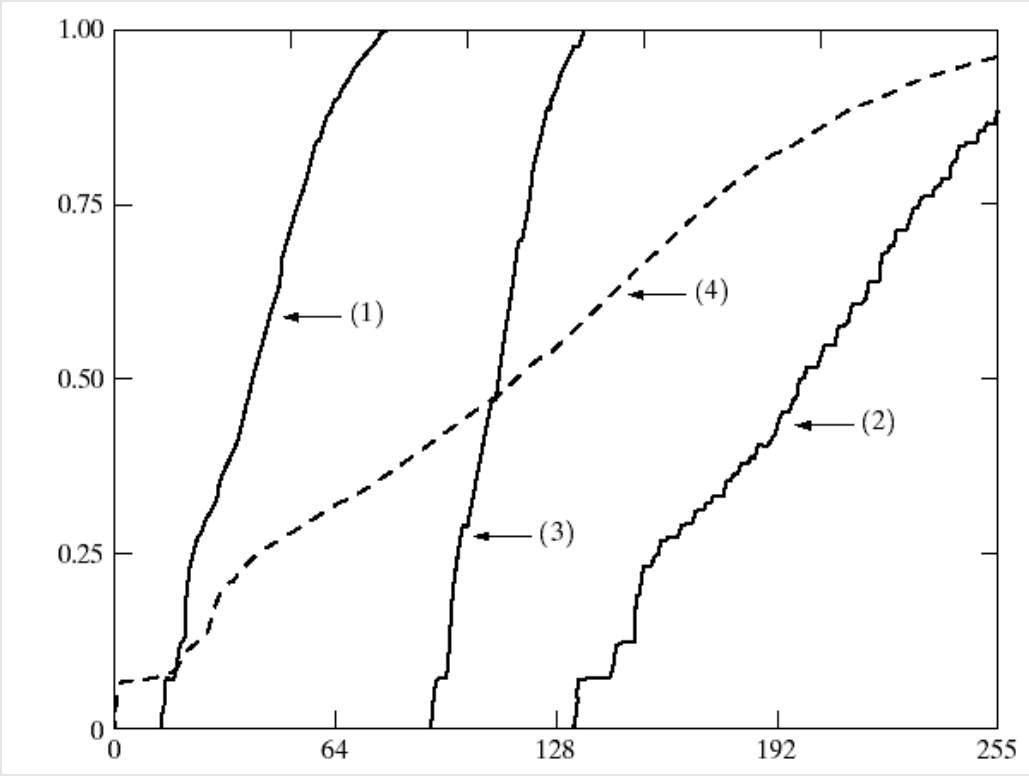




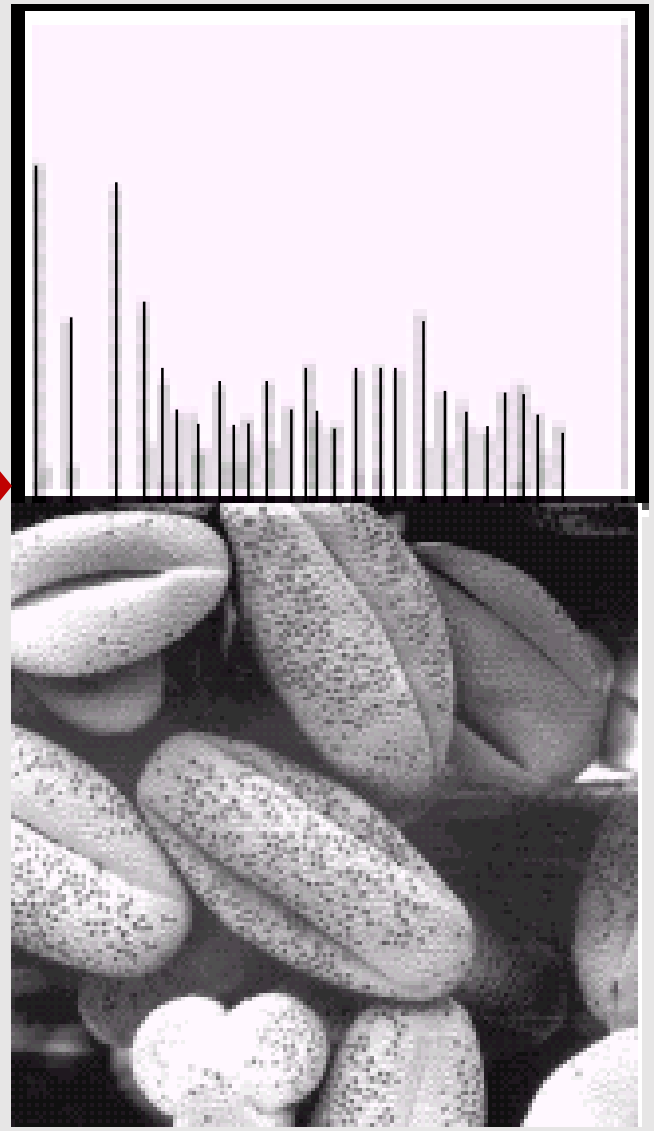
The function 1 was used to equalise the dark image

Histogram Equalisation Examples

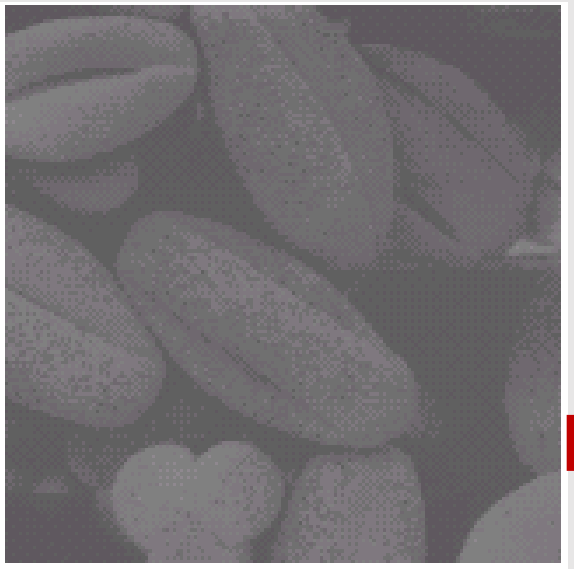


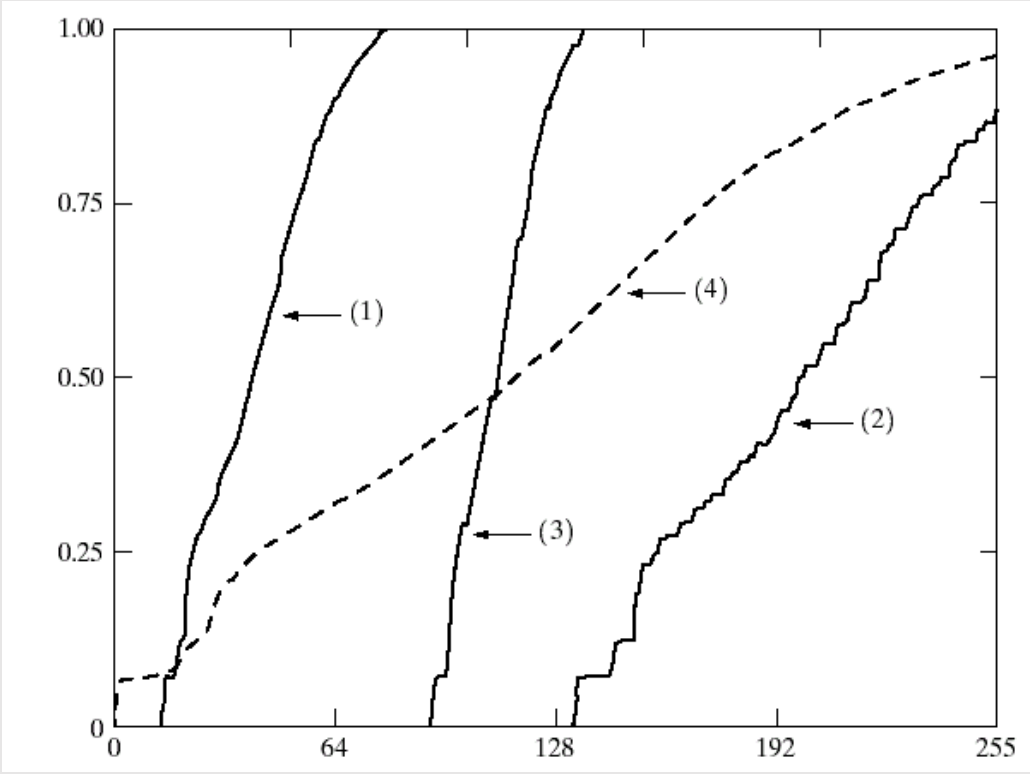


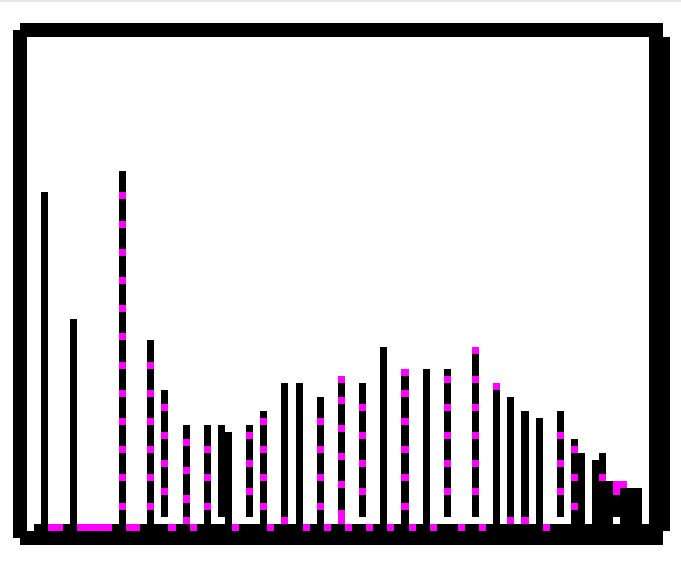
The function 2 was used to equalise the bright image



Histogram Equalisation Examples

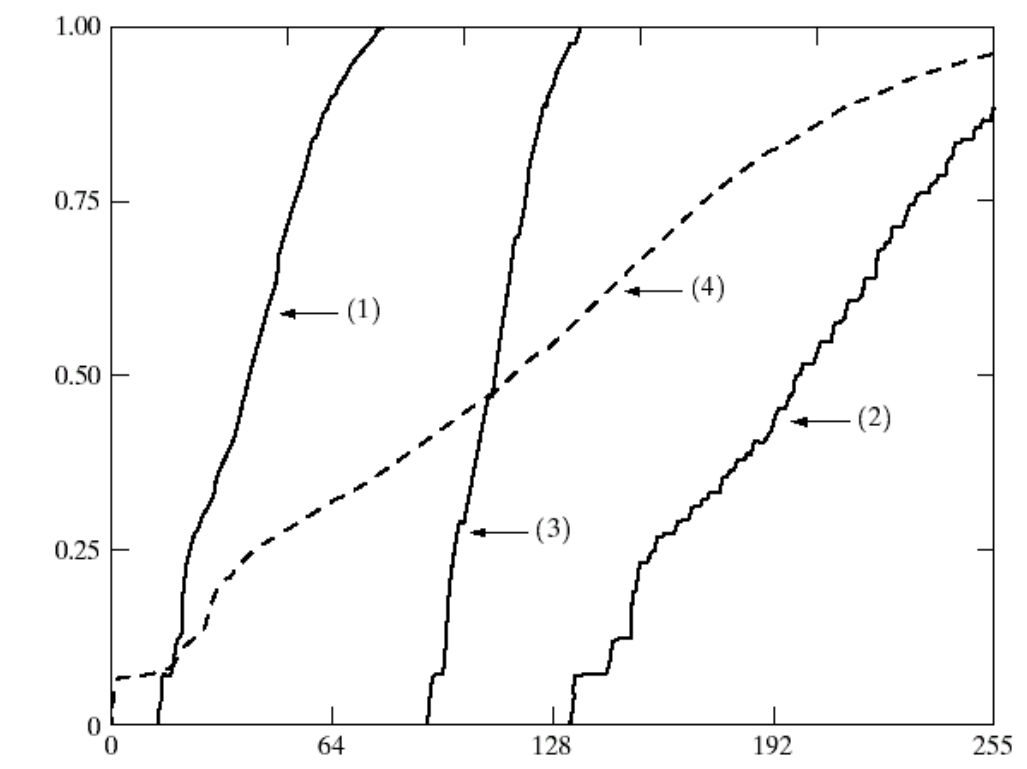






The function 3 was used to equalise the image

Histogram Equalisation Examples



The function 4 was used to equalise the image

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

Suggestions

Now you should:

- Play in different images
- Do Histograms of images
- Do Histogram equalisation