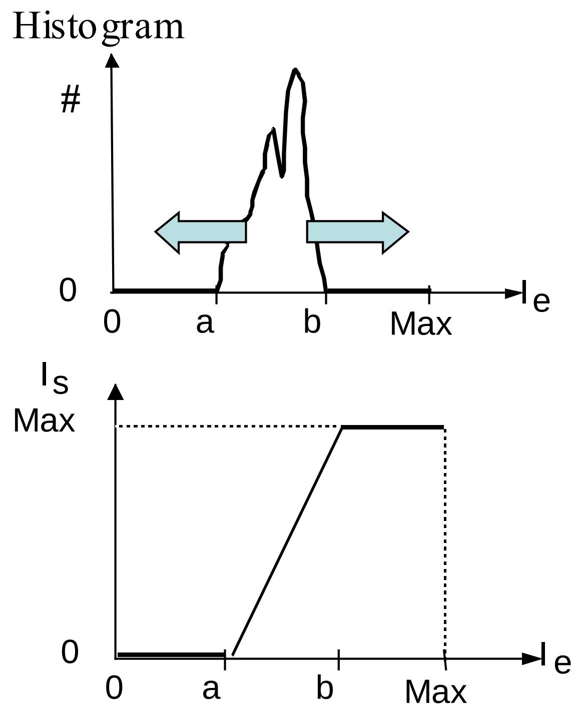
Chapter 2

Fundamentals of Image processing

Histogram transformation

Contrast enhancement by histogram stretching

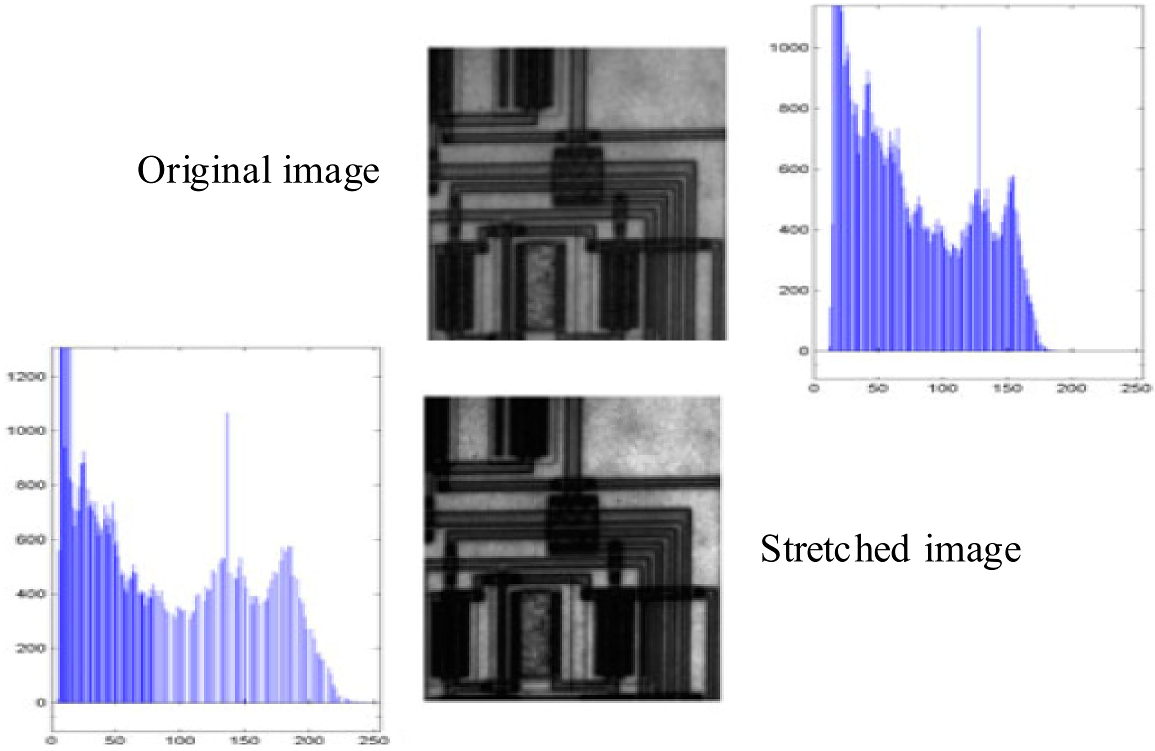


Histogram stretching

- <u>Histogram stretching</u>:

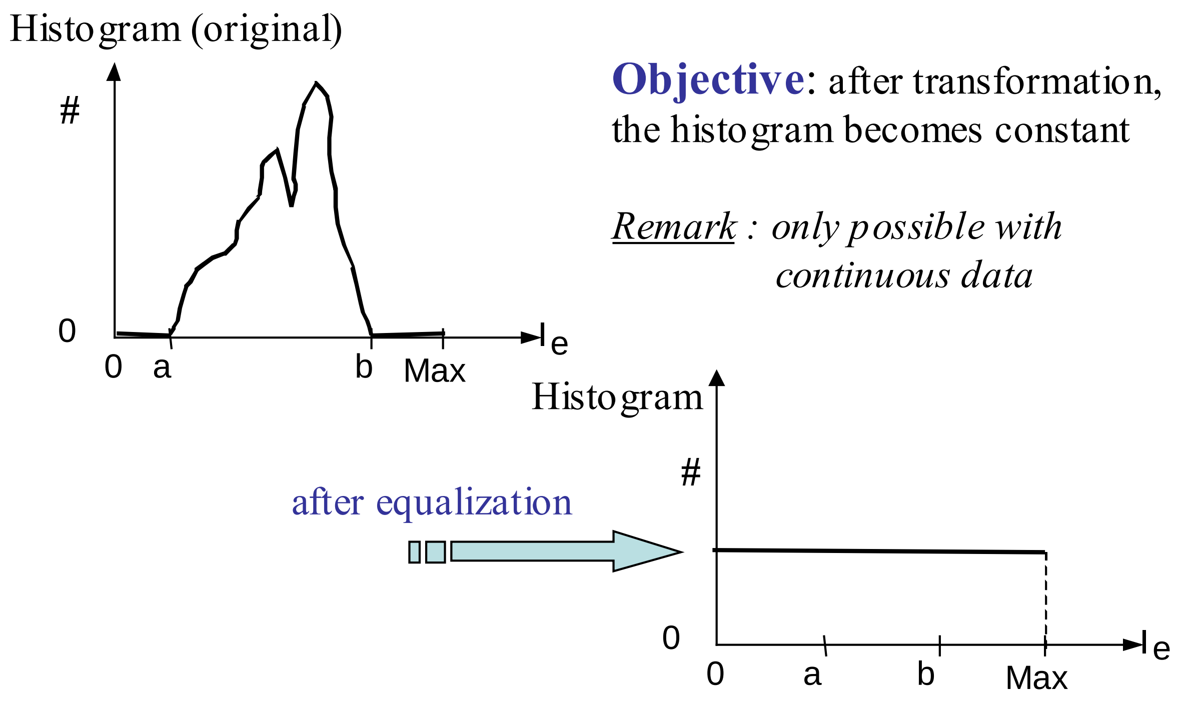
This first histogram transformation performs an image contrast enhancement. For that, we must increase on the histogram (top figure) the range [a, b] of gray-level distribution of the input image I_e. This process is called histogram stretching. A maximum stretching (bottom figure) is performed so that the gray-level distribution of output image I_S occupies the maximum range [0, Max]. Typically the range [a, b] of I_e will be stretched until the range [0, 255] of I_S for an 8-bit pixel coding.

Example of Contrast Stretching



The bottom figure illustrates a histogram stretching of the image '*Circuit*'. The range of values for the original image I_e is [12, 182]. After the histogram stretching the gray-level distribution is displayed on the range [0, 255]. That contains all the gray levels for an 8-bit pixel coding. The image obtained after stretching has a better contrast. The image contents relating to electronic structures of circuits are highlighted.

Histogram Equalization



- Histogram equalization:

The second transformation we are going to consider aims also to improve the contrast enhancement of the image. It includes histogram stretching presented previously with, moreover, a uniform distribution of the gray-levels. After transformation, the histogram becomes constant: each gray-level is represented in the image by a constant number of pixels. It is a “flat” histogram. This transformation is theoretically only possible with continuous data. However the space coordinates and especially the scale of the gray-levels are discrete data. In practice the obtained histogram will be only roughly constant.

Digitalization effect on histogram equalization

Observation : if the original image I_e has ‘k’ gray-levels (k << Max), the output image I_S has less than k gray-levels;

Techniques : we define the cumulated histogram of an image I_e as the function C_{Ie} on [0, Max], with positive integer values.

Especially $C_{Ie}(Max) = N$
where N is the global number of pixels in the image I_e.

The equalization function f (i.e. $I_S = f(I_e)$) is defined by:

$$f(g) = Max \,.\, C_{Ie}(g) / N \qquad \text{(round integer value)}$$

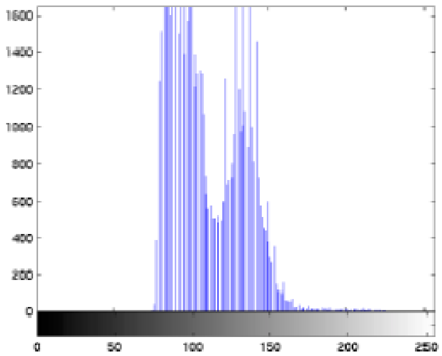
Especially: f(Max) = Max.

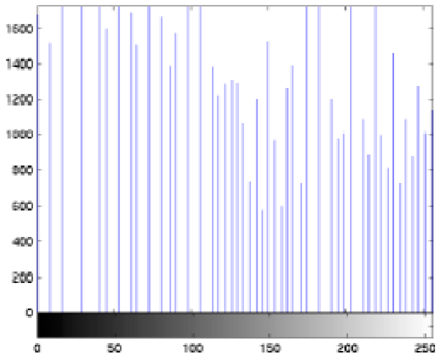
To perform the equalization we use a cumulated histogram. This special histogram inputs for each gray-level « g » the number of pixels having a gray-level **e** lower or equal to **g**. This number is called $C_{Ie}(g)$. As “N” is the total number of pixels in the image I_e, $\frac{C_{Ie}(g)}{N}$ is thus the proportion of the pixels having a gray-level lower or equal to g. After equalization the gray-level “f(g)” will be then the ratio of Max corresponding to this proportion. This fraction is rounded to the nearest integer.
In this case, after equalization, it is possible to obtain the same gray-level for two initial different gray-levels g and g': f(g) = f(g '). The number of gray-levels in the image I_S can thus be lower than "k" (k is the number of gray-levels in the original image I_e).

Example of effect of histogram equalization

original image and its histogram

image and its histogram after equalization





Visually this first example of equalization enhances the image contrast. The histogram obtained after equalization is spread out over the entire scale of gray-levels. The discrete data of the gray-levels does not allow you to obtain a strictly flat histogram.

Contrast enhancement: example and comparison

Original

Histogram stretching

Equalization

This second example shows the result of a simple histogram stretching and the result of a histogram equalization. The contrast enhancement is better after the histogram equalization which more easily detects structures located in the shade.

In fact any strongly represented gray-level is stretched while any weakly represented gray-level is merged with other close levels.