Image Enhancement

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References

- Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Third Edition, Pearson Education, 2008:
  - Histogram Equalization: Chapter 3.3.1

- https://en.wikipedia.org/wiki/Histogram_equalization

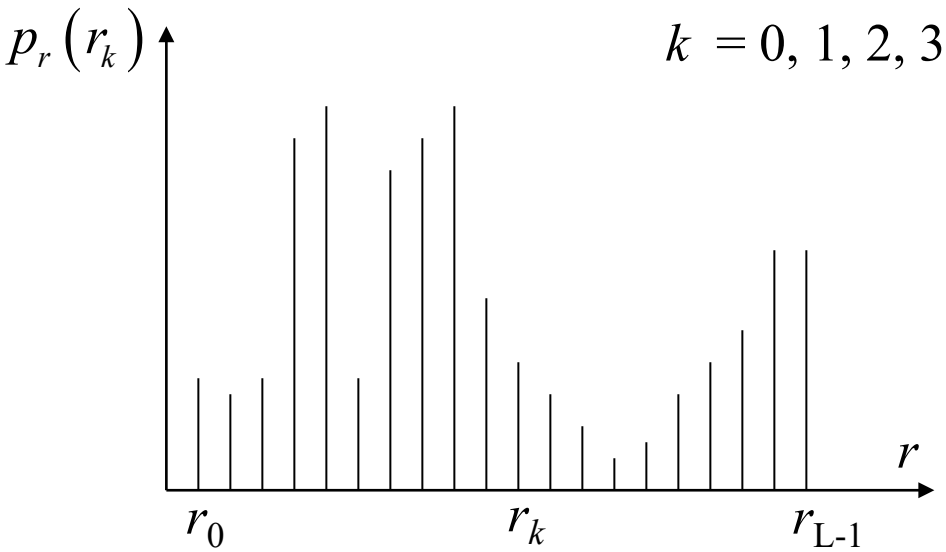
Image histogram

- A digital image with L gray levels r_k. The probability of occurrence of gray level r_k is given by

$$p_r(r_k) = \frac{n_k}{N} \quad \text{where} \quad n_k = \text{number of pixels with gray level } r_k$$

$$N = \text{total number of pixels in an image}$$

$$k = 0, 1, 2, 3, \ldots, L\text{-}1$$



Images with different histograms

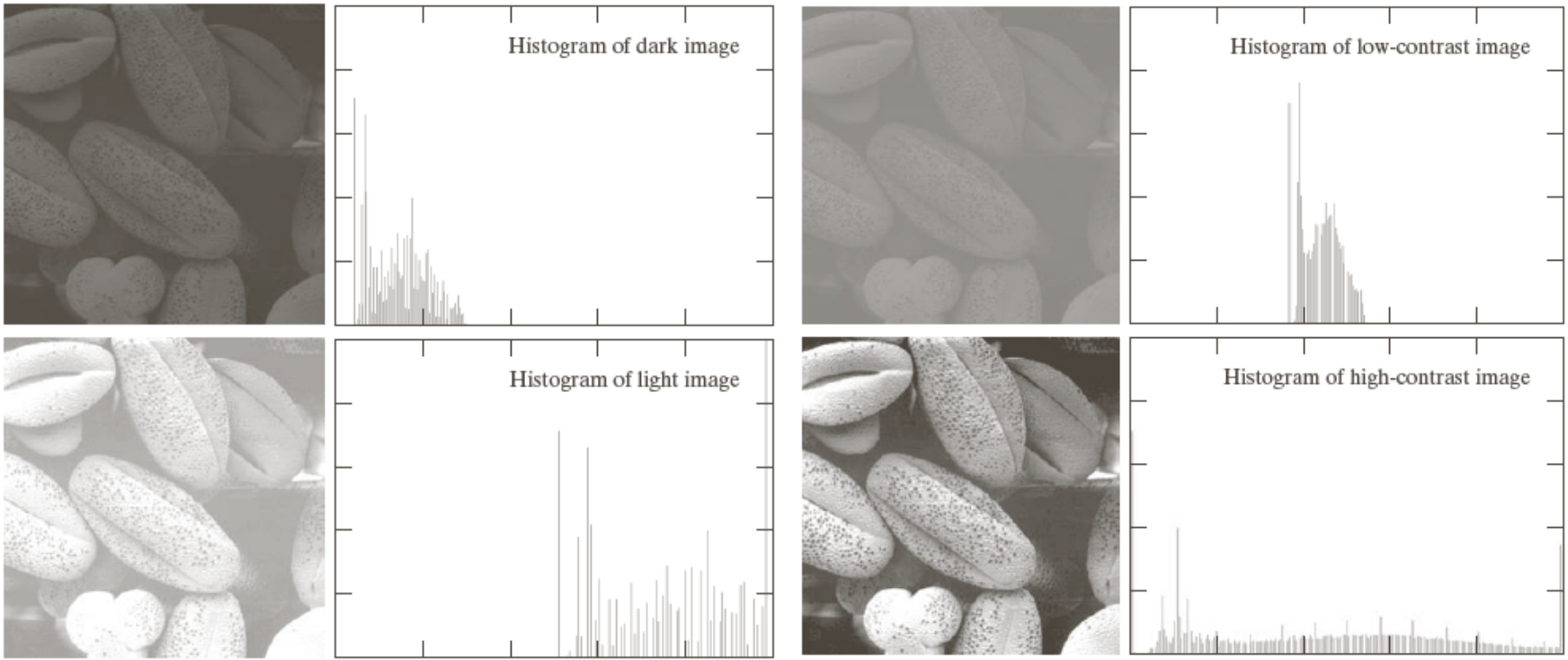
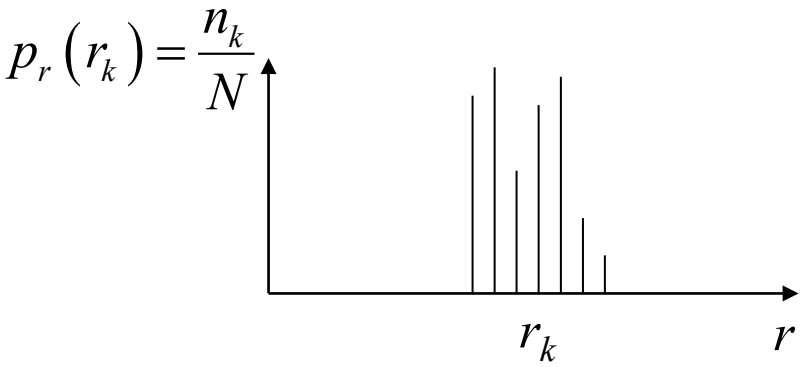
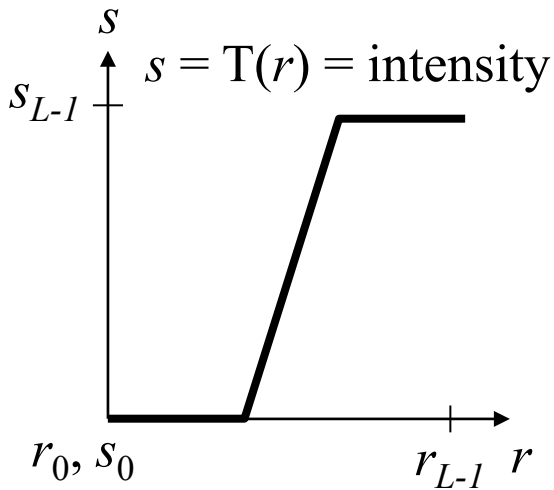


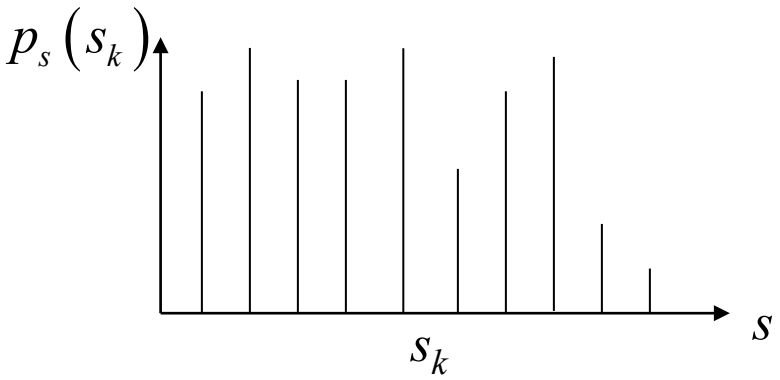
FIGURE 3.16 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms.

Contrast stretching

Histogram of a low contrast image



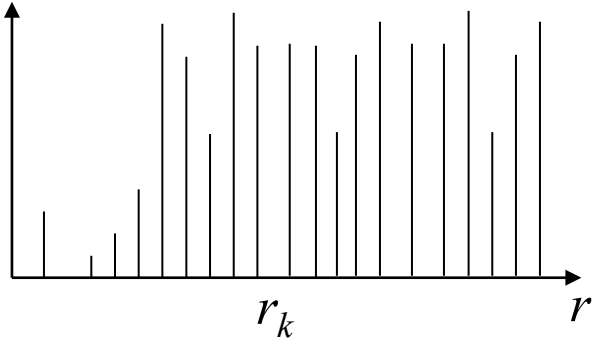


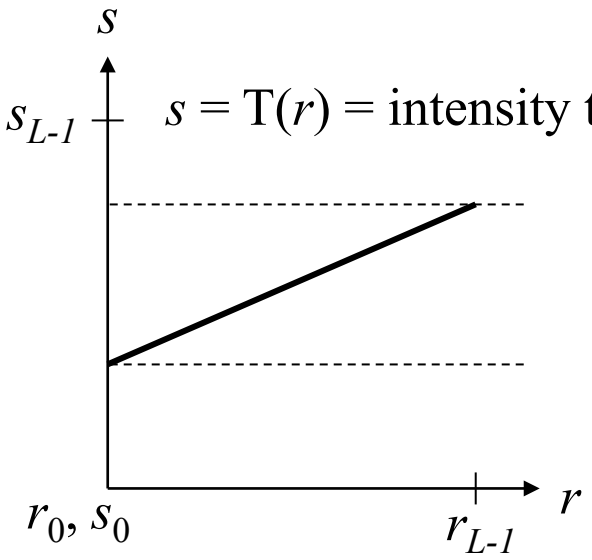


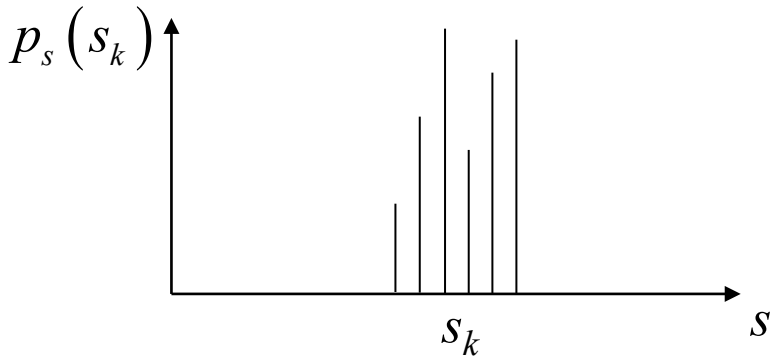
Contrast compressing

Histogram of a high contrast image

$$p_r(r_k) = \frac{n_k}{N}$$







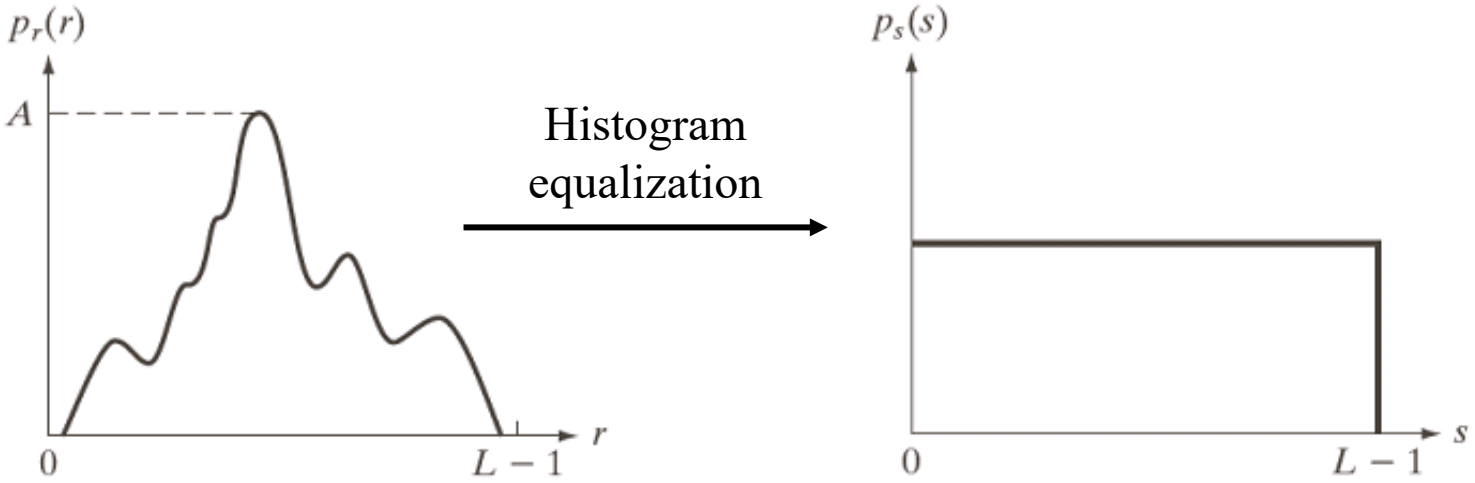
Histogram equalization

- We want an image with output intensity values that approx. follow a *uniform distribution*.

- That is, a flat histogram, where each gray level, r_k, appears an equal number of times, i.e., N/L times,
  - L is the number of gray levels
  - N is the total number of pixels in the image

- The intensity transformation is $s = T(r)$, such that
  - (a) $T(r)$ is single-valued and non-decreasing in the interval $0 \leq r \leq 1$
  - (b) $0 \leq T(r) \leq 1$ for $0 \leq r \leq 1$

Histogram equalization



a b

FIGURE 3.18 (a) An arbitrary PDF. (b) Result of applying the transformation in Eq. (3.3-4) to all intensity levels, r. The resulting intensities, s, have a uniform PDF, independently of the form of the PDF of the r's.

Histogram equalization transform

- The intensity transformation is the cumulative distribution function (CDF) of r, which is represented by

$$s = T(r) = \int_0^r p_r(w)dw$$

- The discrete implementation is given by

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{N} = \sum_{j=0}^{k} p_r(r_j)$$

where
s_k is the output intensity
r_k is the input intensity
n_j is the number of pixels with gray level r_j
$k = 0, 1, 2, 3, \ldots L\text{-}1$ (total number of gray levels is L)

Example 2

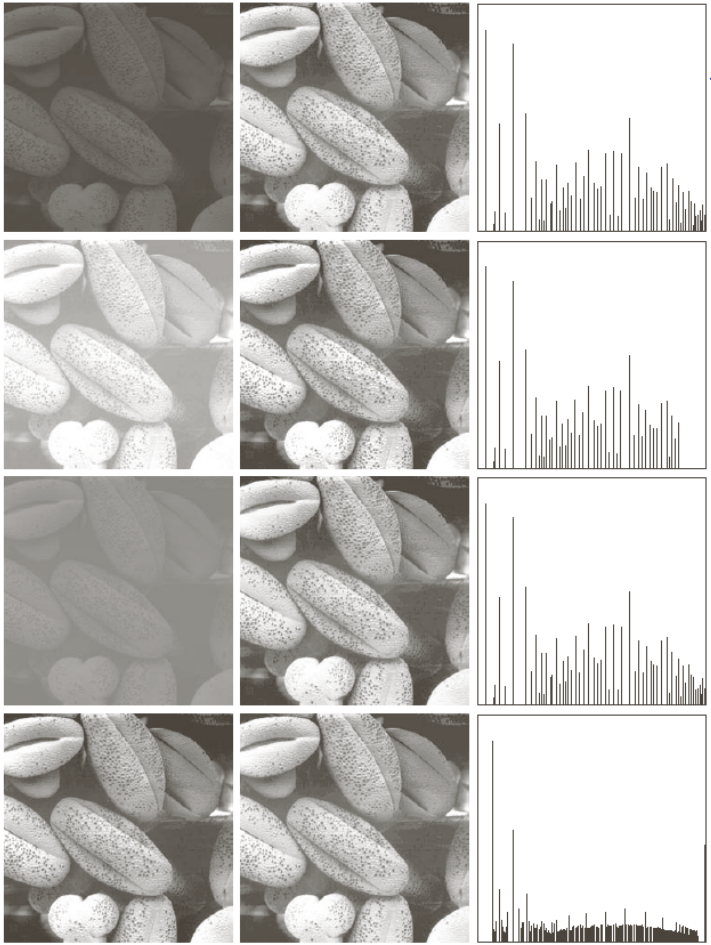


FIGURE 3.20 Left column: images from Fig. 3.16. Center column: corresponding histogram-equalized images. Right column: histograms of the images in the center column.

Histogram equalization

- Histogram equalization can significantly improve image appearance
  - Automatic
  - Computationally efficient

- Good pre-processing step
  - Account for different lighting conditions
  - Account for different camera/device properties

Local histogram equalization

- Apply histogram equalization about a neighborhood around (x,y)
- Transform the gray level for pixel (x,y)
- Move the neighborhood over the rest of the image

Local histogram equalization

Reveals details in local areas

Original | Global Histogram | Local Histogram

Summary

- Image histogram
- Histogram equalization
- Local histogram equalization
- More examples and details can be found at
  - https://en.wikipedia.org/wiki/Histogram_equalization