Lab3: Contrast, equalization and quantization.

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1 Suplementary Notes

Let $u : ([0, N-1] \times [0, N-1] \cap \mathbb{Z}^2) \to [a, a+K-1] \cap \mathbb{Z}$ be an image, N and K are positive integers, $a \in \mathbb{Z}$. Note that we have assumed that the image takes K integer values. The random variable $X(i,j) =$ the gray level of the image in the pixel (i,j). The distribution function of X then will be:

$$F_u(\lambda) = P(X \leq \lambda) = \frac{\text{Number of pixels } (i,j) \text{ such that } u(i,j) \leq \lambda}{N^2}$$

where $\lambda \in \{a, ..., a+K-1\}$. Its density function is the relative frequency of pixels with gray level λ, that is,

$$f_u(\lambda) = \frac{\text{Number of pixels } (i,j) \text{ such that } u(i,j) = \lambda}{N^2},$$

where $\lambda \in \{a, ..., a+K-1\}$.
Histogram equalization. If we make the change of variable:

$$v(i,j) = \left[\frac{F_u(u(i,j)) - F_u(a)}{1 - F_u(a)}(L-1) + 0.5 \right]$$

then v takes integer values in $[0, L-1]$.

Exercise 1. **Linear Contrast Changes**

Given a grayscale image with low-contrast, increase its contrast and, for the resulting image, perform de following operations:

(a) Expand the dark tones [0 0.4].

(b) Expand the light tones [0.6 1.0].

(c) Invert contrast (negative).

(d) Crop the levels higher then 0.7. (clipping).

(e) Binarize at the level 0.5.

Exercise 2. **Nonlinear Contrast Changes**

Exercise 2a. Discuss briefly how you think the value of gamma (< 1 or > 1) affects the light and dark levels of an image when performing a nonlinear contrast change.

Exercise 2b. Select an image with low contrast and apply nonlinear contrast change to visualize the dark details of the image without decreasing too much the overall contrast of the image. What value of gamma do you use?

Exercise 3. **Image Histogram Equalization**

Exercise 3a. Display: (a) the histogram of an RGB image (R, G, B separate histograms), and (b) the histogram of a grayscale image.
Exercise 3b. Implement a function to perform image equalization. Use it to equalize several images. Display the result of equalization and compare the histograms of the original images with the equalized ones.

Exercise 4. **Image Entropy**

Implement a function to calculate the entropy of an image and compare the entropy of the original image and an equalized version of the same one.

Exercise 5. **Quantization**

Exercise 5b. Determine experimentally the smallest number (approximately) of levels for which the quantization is unnoticeable for the eye.
Exercise 5c. Binarize an image using the attached *uniform_quantizer.m* function.

Exercise 6. **Quantization**

Having quantized an image with 3 levels, perform a piece of art just like Andy Warhol. Generate an image with double the original size and duplicate it 4 times, and use the following color palettes (R-G-B):
- Palette 1: (a) 32-31-125, (b) 140-177-37, (c) 255-249-8.
- Palette 2: (a) 236-2-123, (b) 254-250-3, (c) 2-122-234.
- Palette 3: (a) 125-66-146, (b) 125-187-244, (c) 238-134-9.
- Palette 4: (a) 236-107-5, (b) 251-255-168, (c) 145-183-10.

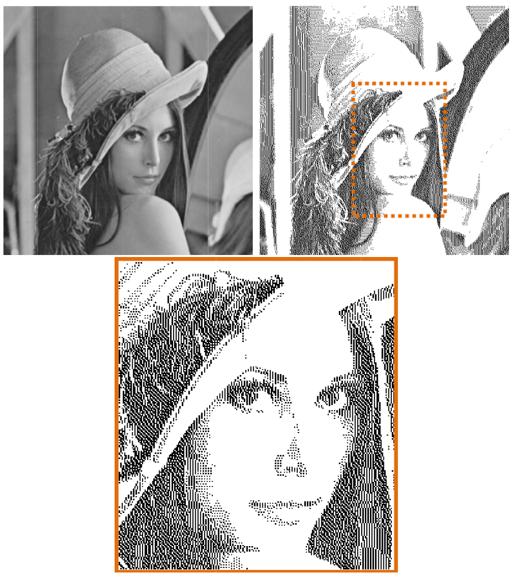
In order not to waste time, these arrays contain the corresponding RGB components:
R = [32 140 255; 236 254 2; 125 125 238; 236 251 145];
G = [31 177 249: 2 250 122; 66 187 134; 107 255 183];
B = [125 37 8; 123 3 234; 146 244 9; 5 168 10];

Exercise 7. Quantitative Criteria of Fidelity

Compute both σ_{ls} and *PSNR* metrics for a given image and its modified versions after performing a uniform quantization. Interpret the results.

Exercise 8. (OPTIONAL) Halftoning

Many printers and monitors have limited range of levels that can be displayed. We can increase the range of intensities by using multiple pixels of each intensity that the peripheral can display, ie, using some patterns. The use of patterns (*dithering*) is based on the spatial integration performed by eye, that is, when we see areas with very fine details from a sufficient distance we actially perceive the average of the area.



This phenomenon is used to print photographs in newspapers and books using the technique of semitones (*halftoning*). At each pixel position a black circle with its area proportional to the darkness of a pixel of the original image is printed. In newspapers, it is common to use a resolution of 50 or 60 pixels per inch, while for books or magazines a resolution of 150 dots per inch is used.

The black and white printers can approximate points of variable area by printing small patterns. For example, a 3 by 3 area of binary (black or white) pixels can be used to represent 10 different gray levels. In general, a group of NxN binary pixels can represent N^{2+1} different levels of gray. Basically, halftoning sacrifices spatial resolution for greater resolution of intensity.

GOAL: analyze both *SampleUsage* and *floydHalftone* Matlab files included in the Lab *.zip* file. Try to run it and show the obtained results. Make a brief explanation of the algorithm (pseudocode could be a nice option).