INSTITUTO SUPERIOR DE ENGENHARIA DE LISBOA
MESTRADO EM ENGENHARIA INFORMÁTICA E DE COMPUTADORES
MESTRADO EM ENGENHARIA INFORMÁTICA E MULTIMÉDIA
IMAGE PROCESSING AND BIOMETRICS

Laboratory Project 1 - 1st semester, 2021/2022 (October, 26)
Due Date (Code and Report): December, 6

Submit the code along with the report containing the experimental results, as well as the corresponding analysis and comments, into the Moodle system.

1. **[MATLAB]**.
   Exercise 4 of the Laboratory Class 1 guide.

2. **[OpenCV and your chosen/preferred programming language]**.
   Exercise 2 of the Laboratory Class 2 guide.

3. **[MATLAB or OpenCV]**.
   The `GrayscaleImages.zip` file contains a set of grayscale images, acquired with different methods on different scenarios.

   (a) For each image and its negative version, compute the brightness, contrast, and entropy values. Present the histogram of each image. Comment on these results.

   (b) For each original image, apply an adequate operation to improve its contrast, using an intensity transform with a lookup table. Describe the operation chosen for each image and show the resulting image, its brightness, contrast, entropy values and its histogram. Report the experimental results. Comment on these results.

   (c) For each image, apply the histogram equalization and the histogram specification techniques to improve its contrast. Show the resulting image and its histogram. Report the experimental results. Comment on these results.

4. **[MATLAB or OpenCV]**.
   The `NoisyImages.zip` file contains a set of original grayscale images as well as four different noisy and distorted versions from these images.

   (a) For each image noisy/distorted image: identify the types of noise/distortion; propose a technique to restore it to its original contents. Explain the proposed technique.

   (b) Apply the proposed techniques on all the noisy/distorted images of the `NoisyImages.zip` file. Compare it against the original version using the *measures of image comparison*, found at the end of this document. Comment on these results.

5. **[MATLAB or OpenCV]**.
   Develop the digital image processing application **CodeCardGenerator**, which generates color and grayscale images, containing a code card, with random content, in a matrix form, as shown in Figure 1.

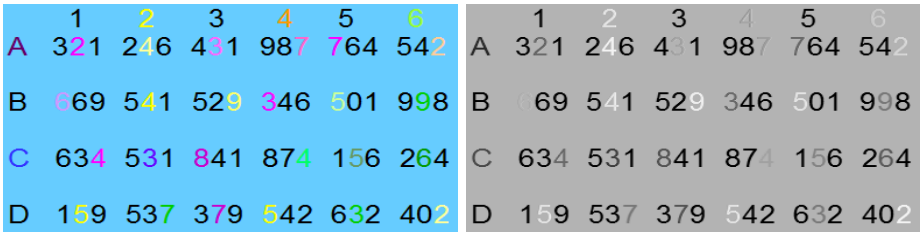

Figure 1: Two examples of code card images: (a) color version (b) grayscale version

   (a) Describe your proposed solution for the **CodeCardGenerator** application.

   (b) Report five different images generated with the application. Comment on the results.

6. **[MATLAB or OpenCV]**.
A *Completely Automated Public Turing test to tell Computers and Humans Apart* (**CAPTCHA**) can be defined as a type of question-response test to determine whether or not the user is human, `http://www.captcha.net/`.

Figure 2: Two examples of CAPTCHA images from: (a) `http://www.captcha.net/` and (b) `https://en.wikipedia.org/wiki/CAPTCHA`

(a) Develop a **CAPTCHA** application, that produces grayscale and color images on both JPEG and PNG format, with different resolutions and different levels of challenge/difficulty to the user. Describe your proposed solution.

(b) Report five different images generated with the application. Comment on the results.

MEASURES OF INDIVIDUAL IMAGE ASSESSMENT

For an image I with spatial resolution $M \times N$:

(i) **Brightness** of I, can be assessed by the mean intensity value, defined as

$$m_I = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} I[m,n]. \tag{1}$$

(ii) **Contrast** of I, can be assessed by

$$c_I = 20 \log_{10} \left(\frac{mx_b + 1}{mi_b + 1} \right), \tag{2}$$

where mx_b and mi_b, are the maximum and minimum intensity values, respectively.

(iii) **Predictability** of I, can be assessed by the entropy defined as

$$H_I = -\sum_{i=0}^{L-1} p(x_i) \log_2(p(x_i)), \tag{3}$$

L is the number of grayscale levels and $p(x_i)$ is the probability of occurrence of each pixel x_i. It measures the randomness or the predictability of an image. We have $0 \leq H_I \leq \log_2(L)$, with zero meaning a constant image (full predictability) and $\log_2(L)$ corresponds to maximum uncertainty (uniform histogram).

MEASURES OF IMAGE COMPARISON (BETWEEN TWO IMAGES I_1 AND I_2)

(i) **The difference in brightness, contrast, and entropy**, defined as

$$\Delta_m(I_1, I_2) = m_{I_1} - m_{I_2}, \qquad \Delta_c(I_1, I_2) = c_{I_1} - c_{I_2}, \qquad \text{and} \qquad \Delta_H(I_1, I_2) = H_{I_1} - H_{I_2}, \tag{4}$$

can be applied for image comparison.

(ii) **Mean Squared Error** (MSE), defined as

$$MSE(I_1, I_2) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} (I_1[m,n] - I_2[m,n])^2. \tag{5}$$

(iii) **Mean Absolute Error** (MAE), defined as

$$MAE(I_1, I_2) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} |I_1[m,n] - I_2[m,n]|. \tag{6}$$