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 2 - 2023/2024 (November, 20)
Due date (Code and Report): January, 8

Please submit the code and the report on the Moodle system. You can find more details on the report at the end of this document.

1. The `BiometricMedicalGrayscaleImages.zip` file contains a set of medical exam images.

   (a) For each image, display the centered spectrum (module and phase) and the histogram. Report the brightness, contrast, and entropy values.

   (b) Apply DIP techniques at your choice to each image, to attain better quality versions for human analysis and understanding. Show the original and the enhanced image side by side. Report the brightness, contrast, and entropy values of the enhanced images.

2. The `GrayscaleNoisyImages.zip` and `RGBNoisyImages.zip` files contain several grayscale and color images. For each image, we have the original version and some noisy/distorted versions.

   (a) For each image, identify the problems and the undesired effects.

   (b) For each image, propose and apply a restoration technique. Show the original and the enhanced image side by side. Check on the results with adequate standard metrics.

3. The need of generating small color images with random letters and/or numbers, as the ones shown in Figure 1, arise in some computer applications. These images usually appear in Web applications to assure that the user is really a human being (*I'm not a robot*) and to prevent some software automated actions.

Figure 1: Examples of captcha images from https://en.wikipedia.org/wiki/CAPTCHA.

   (a) Develop a CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) application for this purpose. Propose an algorithm to generate this type of images. The randomly generated images should contain only *Web safe colors*. Describe all the steps taken by the proposed algorithm.

   (b) Report experimental results with 5 images stored as JPG files and 5 images stored as PNG files. Check if the JPEG compression introduces extra artifacts on the generated images.

4. Consider the DIP application for handling face images, developed in exercise 7 of Laboratory Project 1.
   (a) Add the features of *face detection* and *face recognition* (for five users).
   (b) Report the experimental results for both features.

5. Consider the DIP application for handling fingerprint images, developed in exercise 8 of Laboratory Project 1.
   (a) Devise a fingerprint recognition system with the features of *identification* and *verification* (for five users).
   (b) Report the experimental results for both features.

SINGLE IMAGE ANALYSIS

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

(i) **Brightness** of I, is given by its average intensity

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

(ii) **Contrast** of I, is given by

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

with mx_b and mi_b, denoting the maximum and the minimum image intensity.

(iii) **Predictability** of I, is given by its entropy

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

with L being the total number of grayscale values and $p(x_i)$ the probability of occurrence of each pixel, x_i. We have $0 \leq H_I \leq \log_2(L)$, with zero corresponding to a constant image (total predictability) and $\log_2(L)$ corresponding to maximum uncertainty (uniform histogram).

METRICS FOR IMAGE COMPARISON (BETWEEN IMAGES I_1 AND I_2)

(i) The difference between **brightness, contrast, and entropy**, given by

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

may be considered.

(ii) **Mean Squared Error** (MSE), given by

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

(iii) **Mean Absolute Error** (MAE), given by

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

(iv) **Signal to Noise Ratio** (SNR), defined as

$$SNR(I_1, I_2) = 10 \log_{10} \left(\frac{\sum_{m=0}^{M-1} \sum_{n=0}^{N-1} I_1^2[m,n]}{\sum_{m=0}^{M-1} \sum_{n=0}^{N-1} (I_1[m,n] - I_2[m,n])^2} \right) \quad [dB]. \tag{7}$$

Here are some relevant aspects about the report intended for this laboratory project:

(1) The report must be succinct and organized into five sections, one per exercise.

(2) Each section must be organized into sub-sections, with the relevant aspects of the devised solution.

(3) For each exercise, the report must have a clear description of the response to the aspects requested in the statement. It should also contain all requested experimental results and the respective comments, analysis, and explanations.

(4) The report should not contain the written code. This must be submitted in a separate electronic format, duly commented and organized.