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

1st semester, 2021/2022

Exam 1 February, 4 ; 7:00 pm

- R1 - Mid-term (repetition), 1h30, exercises **1, 2, 3, 4, and 5**.
- R2 - End-term (repetition), 1h30, exercises **6, 7, 8, 9, and 10**.
- GE - Global Exam, 2h30, exercises **1, 4, 5, 7, 8, 9, and 10**.

You can consult your class notes, with 2 A4 pages (R1 or R2) or 4 A4 pages (GE).
Explain, in detail, all your answers. Write down all the hand calculations that you carry out.

1. {R1||GE} The square monochrome image I, with $n = 7$ bit/pixel, has the histogram shown on the table. The gray levels without any occurrence are not displayed on the table.

Gray Level	5	10	20	30	40	50	60	m_x
Ocurrences	124	100	100	100	100	100	100	300

   (a) {1.25||1.0} Indicate the spatial resolution of the image and the value of m_x, knowing that it corresponds to the maximum of intensity. Is it a high brightness and contrast image?

   (b) {1.25||1.0} Compute the entropy, energy, power, and average intensity of I.

   (c) {1.25||1.0} Present, in table form, the histogram of the negative version of this image, designated by I_n. Compare the entropy value of I with the entropy value of I_n. Comment the result.

2. {R1} The following questions refer to the functioning of biometric systems.

   (a) {1.25} Explain the meaning of the following concepts: (i) *failure to enroll*; (ii) *false accept rate*; (iii) *false reject rate*.

   (b) {1.5} Provide an outline of the information contained in a biometric system's record database. indicate how this information is updated and used in the registration and verification/identification phases.

3. {R1} The intensity transformations T_1, T_2 and T_3 are defined as

$$T_1[x] = \begin{cases} 2x, & 0 \leq x \leq 120 \\ 180, & 121 \leq x \leq 150 \\ x, & 151 \leq x \leq 255 \end{cases}, \quad T_2[x] = \begin{cases} 0, & 0 \leq x \leq 20 \\ 31, & 21 \leq x \leq 31 \end{cases} \quad \text{and} \quad T_3[x] = \begin{cases} x, & 0 \leq x \leq 100 \\ 0, & 101 \leq x \leq 127. \end{cases}$$

   (a) {1.5} Sketch the three functions. For each function, indicate: the functionality; the image depth, in bit/pixel, for which it is intended; the image resolution for which it is intended; if it is invertible.

   (b) {1.5} Consider the transformation T_3 over images of spatial resolution 5×5. Is it possible that applying this intensity transformation generates an output image with the same energy as the input image? If so, provide an example of this situation. Otherwise, justify the impossibility.

   (c) {1.5} Let I_3 be defined as

$$I_3 = \begin{bmatrix} 34 & 4 & 1 & 2 \\ 0 & 12 & 88 & 10 \\ 11 & 10 & 76 & 0 \\ 40 & 0 & 0 & 10 \end{bmatrix},$$

   which resulted from the application of T_3 on the image I. Present a possible input image, I, knowing that its energy is higher than that of I.

4. {R1||GE} The following windows are used in the spatial filtering, being defined by

$$w_1 = \begin{bmatrix} 2 & 2 & 2 \\ 2 & A & 2 \\ 2 & 2 & 2 \end{bmatrix} \quad \text{and} \quad w_2 = \frac{2}{B}\begin{bmatrix} 2 & 1 & 2 \\ 1 & 1 & 1 \\ 2 & 1 & 2 \end{bmatrix}.$$

   (a) {1.5||1.0} Determine the value of A so that w_1 corresponds to a *sharpening* window. Determine the value of B so that w_2 is an appropriate *smoothing* window.

   (b) {1.5||1.0} On the window w_2, consider $B = 2$ and a monochrome image I with resolution 1024×512, and depth of $n = 8$ bit/pixel. To filter I, through w_2, indicate the maximum number of additions and multiplications performed, in the worst case. Considering optimizations, is it possible to perform this filtering without resorting to any multiplications?

   (c) {1.5||1.0} Consider $A = B = 2$ and $w_3 = w_1 - w_2$. Let the monochrome image be I with a resolution 512×512, and a depth of $n = 8$ bit/pixel, such that the first 256 columns have constant content equal to 10 and the remaining 256 columns have constant content equal to 200 .Describe the content of the image I_3, which results from the spatial filtering of I, with the window w_3.

5. {R1||GE} Consider the following questions about image processing techniques.

   (a) {1.5||1.0} What is the histogram specification technique? Typically, in what situations is it successfully applied?

   (b) {1.5||1.0} What are the reasons that lead to the success of the median filter in removing impulsive noise (*salt and pepper*)? What are the criteria for choosing the filter mask? After applying this filter, is it possible to reverse the process and get exactly the original image?

   (c) {1.5||1.0} What are the advantages and disadvantages of frequency domain filtering techniques compared to spatial filtering techniques? Give two examples of problems that are well solved by each of these techniques.

6. {R2} The following questions refer to digital image processing in the frequency domain.

   (a) {1.25||1.0} Consider the 256×256 spatial resolution image filtering algorithm in the frequency domain. After the action of *zero padding*, the dimensions of the image *padded* are $P = 2M$ and $Q = 2N$. Bearing in mind that $D[u,v] = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$, the following filters are defined:

$$H_A[u,v] = \begin{cases} 1, & \text{if} \quad D[u,v] \le 30 \\ 0, & \text{if} \quad 31 \le D[u,v] \le 60 \\ 0{,}5, & \text{if} \quad D[u,v] \ge 61 \end{cases} \quad \text{and} \quad H_B[u,v] = \begin{cases} 0, & \text{if} \quad D[u,v] \le 80 \\ 0{,}5, & \text{if} \quad D[u,v] > 80. \end{cases}$$

   For filters defined by $H_A[u,v]$, $H_B[u,v]$ and $H_C[u,v] = H_A[u,v] + H_B[u,v]$, indicate the type of filtering performed and sketch each filter as an image.

   (b) {1.25} Consider the algorithm described below.

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Input: Image f; High-pass filter H; Scalar a. Scalar b.
Output: Image g.
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1. F[u,v] = DFT[ f[m,n] ];
2. M[u,v] = a + b*H[u,v];
3. g[m,n] = IDFT[ M[u,v]*F[u,v] ];
4. Return g[m,n].
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   State: the functionality of the algorithm and an example of its application; the effect of the constants ‘a’ and ‘b’ and how their values ??should be chosen.

   (c) {1.25} Describe what the *homomorphic filtering* technique consists of and which your goals. What is the image formation model that underlies the application of this technique?

7. {R2||GE} Consider the DFT and DCT transforms.

   (a) {1.25||1.0} Image $f[m,n]$ has energy $E_f = 43$ J and uncentered module of spectrum $|F[u,v]| = \begin{bmatrix} 25 & 1 & 1 & 1 \\ C & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 5 & 1 & 1 & 1 \end{bmatrix}$.

   Compute the value of C. Compute the average intensity of $f[m,n]$.

   (b) {1.5||1.0} Let $g[m,n] = \begin{bmatrix} 4 & 4 & 1 \\ 0 & 1 & 2 \\ 4 & 2 & 4 \end{bmatrix}$ and $G[u,v] = \text{DCT}[g[m,n]]$. Without applying the DCT definition, compute the value of $G[0,0]$.

8. {R2||GE} The following questions pertain to digital color image processing.

   (a) {1.5||1.0} Assume that you have a dark colored image contaminated with Gaussian noise in the color channel B. It is intended to increase the brightness of the image. Indicate, in detail, the procedures to be carried out to carry out this operation.

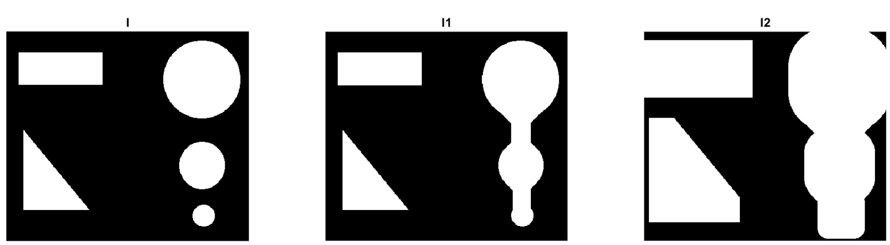
   (b) {1.5||1.0} Starting from the RGB color space with $n = 8$ bit/pixel per component, the RGB' color space was defined, using a representation with $n = 6$ bit/pixel per component. Indicate: the number of distinct colors in the RGB' space; the number of distinct gray levels in the RGB' space; how to reduce the RGB space to the RGB' space.

   (c) {1.5||1.0} Consider that, on an image represented in HSI space, the *color slicing* technique is intended to be applied on the color *pure red*. Present a sketch of the algorithm that performs this operation, explaining the input and output parameters.

9. {R2||GE} Take into account morphological image processing techniques.

   (a) {1.5||1.0} Explain what the structuring element consists of and what are the main criteria to be followed in choosing them.

   (b) {1.5||1.0} The figure shows two morphological operations applied to the image I. Describe the operations and the structurant element, from I, lead to the images I_1 and I_2.



   (c) {1.5||1.0} Consider that on the image I we want to eliminate the smallest circle and keep the remaining objects. Indicate how you would proceed to achieve this objective, through morphological operations.

10. {R2||GE} Consider the following questions about how biometric systems work.

    (a) {1.5||1.0} Biometric recognition of individuals through fingerprint has wide application compared to other biometric modalities. Explain the main reasons that lead to this wide application.

    (b) {1.5||1.0} Consider that a biometric system is used with a certain modality, to be used by two identical twins. Is there a probability of system failure? If it exists, this failure depends of the biometric modality used?

    (c) {1.5||1.0} In the recognition of individuals through fingerprint, it is used to the sectored Gabor filtering. Indicate: what this technique consists of; how the result of Gabor filtering is used in the biometric system.