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

**2nd semester, 2018/2019**

Exam 2 | July, 10 ; 7:00 pm | Available time: 2:30

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**You can consult your class notes, with four A4 pages.**
**Explain, in detail, all your answers. Write down all the hand calculations that you carry out.**

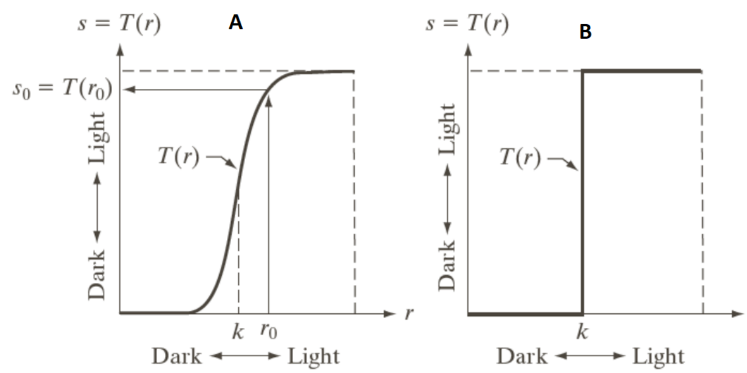
1. Let $I$ be the monochrome image $I = \begin{bmatrix} 5 & 10 & 5 & 10 \\ 5 & 10 & 5 & 10 \\ 5 & 60 & 60 & 0 \end{bmatrix}$.

   (a) $\{1.0\}$ For the image $I$, state: the spatial resolution; the minimum depth resolution, expressed in bit/pixel; the least significant bit plane; the most significant bit plane; the average intensity value.

   (b) $\{1.0\}$ Determine and present the negative version of $I$, designated as $I_n$. Characterize the $I$ and $I_n$ images , regarding contrast (low/medium/high) and brightness (low/medium/high).

   (c) $\{1.0\}$ Display the histograms of the $I$ and $I_n$ iamges. Compute the entropy value of these images. Comment on the result.

2. The figure shows the intensity transformation functions $A$ and $B$.




   (a) $\{1.0\}$ State the functionality associated with each of the $A$ and $B$ functions. For both functions, indicate the role of the $k$ parameter.

   (b) $\{1.0\}$ Present an outline of the lookup table that performs each of these functions. Show examples of situations in which the $A$ function and the $B$ function must be applied.

3. Consider the linear spatial filtering windows defined by

$$w_1 = A \begin{bmatrix} 1 & C & 1 \\ C & B & C \\ 1 & C & 1 \end{bmatrix} \quad \text{and} \quad w_2 = \frac{4}{D+1} \begin{bmatrix} D/4 & (1-D)/4 & D/4 \\ (1-D)/4 & -1 & (1-D)/4 \\ D/4 & (1-D)/4 & D/4 \end{bmatrix}.$$

   (a) $\{1.0\}$ Determine two sets of distinct values for $A$, $B$, and $C$, so that $w_1$ is a smoothing operator.

   (b) $\{1.0\}$ Is it possible to perform a sharpening operator with $w_1$? If possible, indicate a set of values for $A$, $B$, and $C$. If not, justify this impossibility.

   (c) $\{1.0\}$ With $D = 0$, identify the operator made by $w_2$. Determine the range of values for the $D$ parameter and explain the consequences of changing the values of this parameter.

4. Consider the image filtering algorithm in the frequency domain. After the zero padding step, the dimensions of the padded image are $P = 2M$ and $Q = 2N$. Given that $D[u,v] = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$, we define the following filters:

$$H_A[u,v] = D[u,v], \quad H_B[u,v] = 2, \quad H_C[u,v] = \frac{1}{1 + \left(\frac{D[u,v]}{D_o}\right)^{2n}} \quad \text{and} \quad H_D[u,v] = 1 + 4\pi^2 D^2[u,v].$$

(a) $\{1.0\}$ For the four filters, indicate, justifying, the type of filtering or the action performed.

(b) $\{1.0\}$ For the $H_C[u,v]$ filter, indicate the functionality of the $D_o$ and $n$ parameters.

5. The following questions address the computation and use of the $F[u,v]$ spectrum and its module $|F[u,v]|$ and argument $\arg[F[u,v]]$.

(a) $\{1.0\}$ In general terms, what is the information contained in $|F[u,v]|$ and $\arg[F[u,v]]$? In the visualization and observation, in the image form of $|F[u,v]|$ sometimes we opt to visualize the image given by the transformation $\log(1 + |F[u,v]|)$ instead of directly viewing $|F[u,v]|$. What are the reasons and advantages of this option? Justify.

(b) Consider the following algorithm

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Input: Image f[m,n]; Filter H[u,v], on the frequency domain.
Output:   Image g[m,n].
1. F[u,v] = DFT[ log(1 + f[m,n]) ].
2. G[u,v] = H[u,v]  . F[u,v].
3. g[m,n] = exp( IDFT[ G[u,v] ] ) - 1.
4  Retornar g[m,n].
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(i) $\{0.5\}$ Identify the designation and functionality of the algorithm. For what kind of image, is it typically applied successfully?

(ii) $\{0.5\}$ In the algorithm implementation, identify the type of filter to be used in $H[u,v]$, so that to obtain the appropriate results.

6. Consider the pseudo-color and full-color image processing techniques.

(a) $\{1.0\}$ Display a sketch of the intensity transform functions to perform monochrome image coloring, with depth of $n = 8$ bit/pixel, with the intensity to RGB transform technique, as follows:

(i) the intensity values 0, 50, and 100, must correspond to the colors Blue, Green, and Red, respectively;

(ii) the intensity values between 101 and 200 should match the color Yellow.

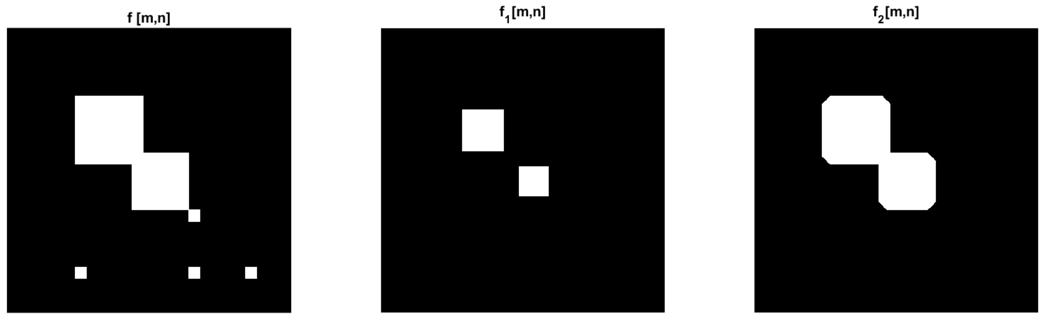
(iii) the intensity values greater or equal than 201 must match the color White.

(b) $\{1.0\}$ Consider the color codes $A = [128, 128, 128]$, $B = [200, 0, 0]$ and $C = [0, 128, 128]$ represented in the RGB color space. Let the color codes in the space HSV $X = [127, 255, 128]$, $Y = [0, 0, 128]$ and $Z = [0, 255, 200]$. Match the color codes in the RGB and HSV spaces.

7. The following questions address the morphological processing of binary images.

(a) $\{1.0\}$ Give two examples of digital image processing problems, in which it is appropriate to resort to morphological processing techniques.

(b) $\{1.0\}$ Consider the binary image $f[m,n]$ shown in the figure. Indicate how to proceed using the morphological operations from the $f[m,n]$ image to obtain the $f_1[m,n]$ and $f_2[m,n]$ images, shown in the figure.




8. The following questions refer to Biometric Systems (BS).

   (a) {1.0} Describe in detail the error indicators associated with BS, namely *false positive* (FP), *false negative* (FN), *true positive* (TP), and *true negative* (TN). Which of these indicators are typically assessed through a confusion matrix?

   (b) {1.0} Fingerprint-based BS resort in some cases to the use of minutiae as key points of the fingerprint. Indicate what the minutiae consist of. For the minutiae detection, what are the main steps to be taken in the digital image processing algorithms?

9. A classifier was trained and evaluated, and the following confusion matrix was obtained $C = \begin{bmatrix} 95 & 2 & 2 & 1 \\ 5 & 87 & 2 & 6 \\ 0 & 2 & 95 & 3 \\ 0 & 0 & 1 & 99 \end{bmatrix}$.

   (a) {1.0} Indicate: the number of classes; the total number of patterns used in the test; the probability of error for each class. Indicate the class for which the classifier appears to function worse.

   (b) {1.0} Pattern recognition systems are composed of two main functional blocks. Identify these blocks and indicate their functionalities. Identify the type of input and output data for these blocks.