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 1 June, 24; 7:00 pm

- R1 - Mid-term (repetition), 1h30, exercises **1 to 6**.
- R2 - End-term (repetition), 1h30, exercises **7 to 12**.
- GE - Global Exam, 2h30, exercises **1, 2, 4, 5, 7, 9, 10, and 11**.

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} Let $I = \begin{bmatrix} 10 & 10 & 10 & 0 \\ 5 & 5 & 5 & 10 \\ 10 & 10 & 10 & 10 \\ 10 & 10 & 5 & 12 \\ 10 & 10 & 5 & 12 \end{bmatrix}$, with a pixel depth of $n = 5$ bit/pixel.

   (a) $\{1.25||1.0\}$ Regarding the image I, present the value of the indicators: spatial resolution, energy, entropy, mean value and total number of bits occupied.

   (b) $\{1.25||1.0\}$ Characterize the image I relative to brightness (low / medium / high) and contrast (low / medium / high).

   (c) $\{1.25||1.0\}$ Display the histogram of the image I and the histogram of its negative version, I_n.

2. {R1||GE} The table shows the intensity transformation designated by T.

Input Pixel	**Output Pixel**
$\{0, \ldots, 40\}$	$\{0, \ldots, 80\}$
$\{41, \ldots, 100\}$	$\{81, \ldots, 127\}$
$\{101, \ldots, 127\}$	127

   (a) $\{1.25||1.0\}$ Regarding T: present an outline of the function; sketch of a lookup table that realizes it; the intended depth of the image; indicate if the T function is invertible.

   (b) $\{1.25||1.0\}$ Compute the I_t image, which results from the application of T on the image $I = \begin{bmatrix} 40 & 40 & 20 & 20 \\ 100 & 127 & 100 & 10 \\ 101 & 101 & 41 & 41 \\ 40 & 20 & 10 & 10 \end{bmatrix}$.

   (c) $\{1.25||1.0\}$ Display an image example A, such that when the T transformation is applied on A, the result is an image, B, with the quadruple energy of A. The image A will have spatial resolution 2×3 and will not have *pixels* with repeated values.

3. {R1} The following questions address digital image processing techniques.

   (i) $\{1.25\}$ In digital image acquisition and training processes, each *pixel* is typically represented by a nonnegative integer. Please state the reason for which values of higher brightness correspond to integers with higher values.

   (ii) $\{1.25\}$ Consider the Histogram Equalization (HE) technique to work in global mode and in local mode. Indicate the purpose of the HE technique. Explain the differences between performing the technique globally and locally.

   (iii) $\{1.25\}$ Consider the LoG operator. Explain the meaning of the acronym LoG and indicate in detail the block diagram of this operator. Give an example of a situation where it is appropriate to use this operator.

4. {R1||GE} Consider the windows w_1, w_2, w_3, and w_4 used for spatial image filtering

$$w_1 = \frac{1}{A}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad w_2 = \frac{1}{B}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}, \quad w_3 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \text{and} \quad w_4 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}.$$

(a) {1.5||1.0} Do these windows refer to linear or non-linear techniques? Enter the values of A and B, so that w_1 and w_2 correspond to *smoothing* operators. Indicate the functionality of windows w_3 and w_4 and examples of application.

(b) {1.5||1.0} Consider the monochrome image I with resolution 128×256 and content equal to 10 in the first 128 columns and content equal to 30 in the remaining columns. Describe the contents of the I_1 and I_3 images, which result from the I spatial filtering, with the w_1 (with $A = 1$) and w_3 windows, respectively.

5. {R1||GE} The following questions address filtering techniques in the frequency domain. Given that $D[u,v] = \sqrt{(u - P/2)^2 + (v - Q/2)^2}$, we define the following filters in the frequency domain:

$$H_1[u,v] = 1 - \exp\left(-\frac{D^2[u,v]}{2D_o^2}\right) \quad \text{and} \quad H_2[u,v] = \frac{1}{1 + \left(\frac{D[u,v]}{D_o}\right)^{2n}}.$$

(a) {1.25||1.0} For each filter: identify the algorithm / technique used to define it; the type of filtering.

(b) {1.25||1.0} For both filters, explain the effect obtained by increasing the values of the D_o and n parameters.

(c) {1.25||1.0} Consider the following statement: *"It is guaranteed that on any input image, the application of $H_1[u,v]$ produces a null mean value image."* State the logical value of this statement.

6. {R1} {2.0} The image $f[m,n]$ has spectrum $F[u,v] = \begin{bmatrix} 24 & 3 + j\sqrt{3} & 3 - j\sqrt{3} \\ -3 + j\sqrt{3} & -3 - j\sqrt{3} & 0 \\ -3 - j\sqrt{3} & 0 & -3 + j\sqrt{3}. \end{bmatrix}$. Calculate the mean value and power of $f[m,n]$.

7. {R2||GE} Consider the *Discrete Cosine Transform* (DCT) applied to images of spatial resolution $M \times N$.

$$F[u,v] = \text{DCT}[f[m,n]] = C[u]C[v] \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f[m,n] \cos\left(\frac{(2m+1)u\pi}{2M}\right) \cos\left(\frac{(2n+1)v\pi}{2N}\right),$$

$$\text{with} \quad C[u] = \begin{cases} \frac{1}{\sqrt{M}}, & u = 0 \\ \sqrt{\frac{2}{M}}, & u \in \{1, \ldots, M-1\} \end{cases} \quad \text{and} \quad C[v] = \begin{cases} \frac{1}{\sqrt{N}}, & v = 0 \\ \sqrt{\frac{2}{N}}, & v \in \{1, \ldots, N-1\} \end{cases}.$$

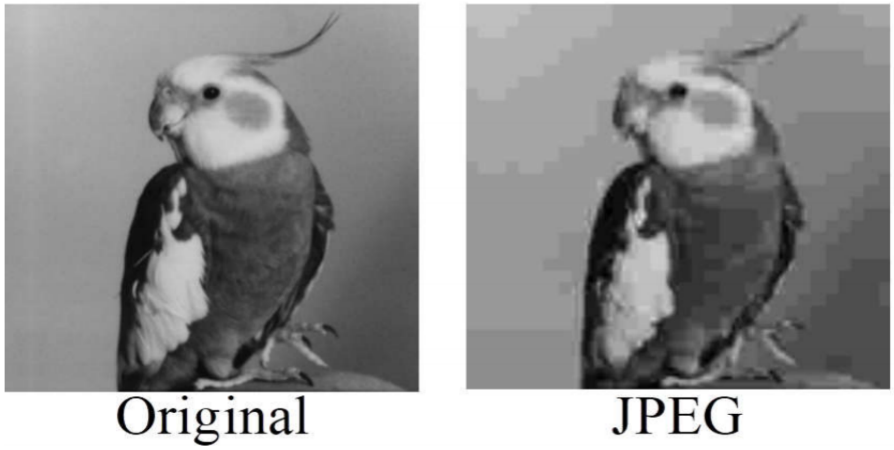
(a) {1.25||1.0} Let I be a monochromatic image with the sum of all pixels equal to 120, spatial resolution 5 3 and resolution in depth of $n = 8$ bit / pixel, whose DCT is D_I. Consider the negative and 90º rotated versions of I, designated by I_n and I_r, respectively. The DCT of these images are given by $D_I n$ and $D_I r$, respectively. Determine the values of $D_I[0,0]$, $D_{In}[0,0]$ and $D_{Ir}[0,0]$.

(b) {1.25||0.5} Consider that you want to perform low-pass filtering on an image, using to the DCT, through the algorithm that follows.

```
Input:  Monochrome image, f[m,n]. Mask H.
Output: Monochrome image, g[m,n].
1. F = DCT(f);
2. G = F * H;
3. g = IDCT[G];
```

Is it possible to do the desired filtering? If yes, indicate how to set the H mask. Otherwise, justify the impossibility.

(c) {1.25||0.5} The figure shows a monochrome image and its JPEG encoded version, with loss. Explain the reasons why the JPEG image has a *"block effect"* aspect. The JPEG encoded image energy is less, equal of above the energy of the original image?



8. {R2} The following questions address the coloring (pseudo-color application) of monochrome images.

   (a) {1.25} Indicate the main reasons for coloring monochrome images. Indicate the two main techniques used to accomplish this goal. In applying these techniques it is compulsory for the codes are represented in the RGB space?

   (b) {1.25} A given monochrome image has a certain noise level. When applying a technique of coloring on the image, the effect of noise became more evident. To remove noise, spatial filtering applies. Indicate how you would perform this spatial filtering, considering the following: (i) the color image is represented in the RGB color space; (ii) the color image is represented in the HSI color space.

   (c) {1.25} 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 space.

9. {R2||GE} The following questions address the processing of color images.

   (a) {1.25||1.0} Consider that if you want a color image, increase the overall brightness without changing color. Indicate the steps of the algorithms to be performed for this purpose considering the following: (i) the images are represented in the RGB color space; (ii) the images are represented in the HSI color space.

   (b) {1.25||1.0} When performing the Histogram Equalization (HE) operation on colored images, is it preferable to choose to implement it in the RGB color space in the HSI color space, or is it indifferent? Justify your answer.

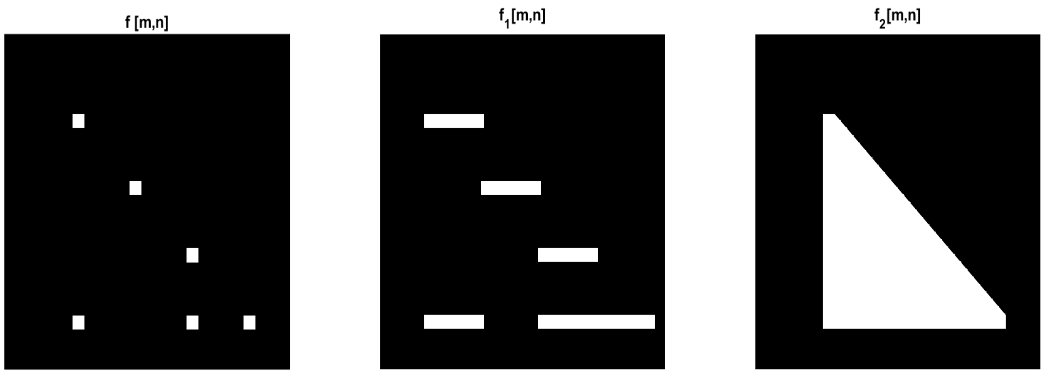
   (c) {1.25||1.0} A given RGB image displays noise on all bands. When converting the image to the HSI color space, it was verified that the noise is present in the bands H and S, and the band I practically does not present noise. This situation is verified in the figure below. Indicate the causes that led to this situation.

(a) Hue. (b) Saturation. (c) Intensity.

10. {R2||GE} The following questions address the morphological processing of binary images.

   (a) {1.25||1.0} Give two examples of actions that are possible through of morphological processing and which are not possible to perform through other techniques.

   (b) {1.5||1.0} Consider the binary image $f[m,n]$ shown in the figure. Indicate how to proceed using the morphological operations from the image $f[m,n]$ to obtain the images $f_1[m,n]$ and $f_2[m,n]$ shown in the figure.



11. {R2||GE} The following questions refer to Biometric Systems (BS).

   (a) {1.5||1.0} For authentication scenarios, describe what is a false positive (FP) and a false negative (FN). Give examples of SB situations, where it is more appropriate to minimize the occurrence of PF, even if this implies an increase in the occurrence of FN. Typically, when FP is equal to zero, what is the most common consequence?

   (b) {1.5||1.0} In some BS, liveness detection techniques are applied. What are these techniques and what are the reasons for its use?

12. {R2} Consider the pattern recognition systems applied within biometric systems.

   (a) {1.5} Display the generic block diagram of a pattern recognition system. Indicate the functionality of each block. Indicate how to proceed to choose, implement and evaluate the operation of each block.

   (b) {1.5} A given classifier was evaluated through a test set. The table presents, for each test set standard, the results of the correct label, along with the label predicted by the classifier.

Correct Label	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
Predicted Label	3	3	1	1	2	2	1	1	2	2	2	2	2	2	3	3	2	3	3	3	2

   State the number of patterns that make up the test set. Display its confusion matrix, the error percentage per class and the overall error percentage, in the test set.